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THE GEOLOGY OF SWITZERLAND TOWNSHIP, MONROE COUNTY, OHIO[1]

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The aim of this report is twofold. It is primarily an attempt to summarize the geologic events that transpired in the past as interpreted from the exposed rocks in Switzerland Township, the Ohio River valley, and in the broader region of Ohio, West Virginia, and Pennsylvania. Secondly, this report summarizes the structural and economic geology of Switzerland Township and immediate environs.

HISTORY AND ECONOMIC SETTING OF SWITZERLAND TOWNSHIP

In April 1819, ten German and Swiss families embarked on a flat boat on the Aar River enroute to Berne, Switzerland, and thence on the Rhine to Antwerp, Belgium. After 48 days aboard the Eugenius, a French vessel bound for New York, they landed at Amboy, New Jersey. Six families purchased teams for the overland trek to Wheeling, West Virginia. At the mouth of Captina Creek at the present site of Powhatan Point, Ohio, they found two Pennsylvania Dutch men who informed them that there was plenty of government land in Monroe County, Ohio. On September 15, Father Tischer and part of his band continued down river 15 miles to Bare's Landing, Ohio Township, and the remainder settled in the hills above Powhatan Point. Switzerland Township, an area of about 28 square miles, was organized by the latter group January 1, 1827.

These early settlers selected a small portion of the maturely dissected Allegheny Plateau (fig. 1) as the site for their new home. To the casual early Swiss observer, the hilly topography of his new home was reminiscent of Switzerland, especially the seemingly never-changing, impenetrable landscape. It is only necessary to walk in the numerous ravines, especially during the spring of the year, or to follow them to their confluence with a larger stream to observe the large amount of rock debris of all sizes and shapes being eroded and undergoing physical and chemical weathering on its route to the sea. Although other eroding forces are at work, running water is the dominant force removing debris from the slowly ever-changing landscape in those "everlasting hills."

The early economy of Switzerland Township was centered around the small cheese and dairy industries located on the divides and high in the heads of valleys. The agricultural economy was supplemented by utilizing some of the thicker beds of poor quality coal, and the limestone and sandstone outcropping in the steep valleys. In the early days transportation was primarily by steamboat on the Ohio River. In later years, the recovery of oil and gas and high grade coal from

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beneath the surface rocks, and the utilization of the industrial water of the Ohio River and its terraces here and in the near vicinity have contributed to this economy.

DESCRIPTION AND ORIGIN OF THE ROCKS OF SWITZERLAND TOWNSHIP AND ENVIRONS

Origin of rocks. The amateur student of earth science as well as the professional geologist can obtain a better understanding of the history of the earth by closely observing the outcropping rocks in the ravines and roadcuts. For it is only the

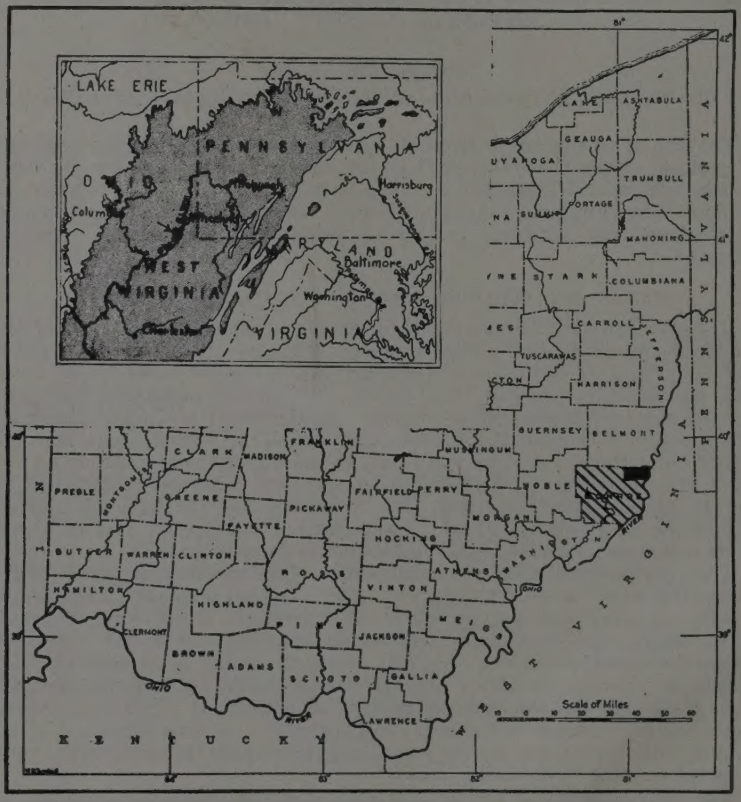

FIGURE 1. Location map. Switzerland Township and vicinity shown in black. Monroe County is cross-hatched. Inset shows position of Switzerland Township (black) in the northern Appalachian Coal Basin (stippled).

rocks themselves that relate the story of the life that flourished and the environmental conditions that existed during their deposition.

Throughout the entire region where coal occurs, the layers of rock are of sedimentary origin. That is, they are made up of sediments such as sand, silt, and clay, derived from weathering of previously formed bedrock, or unconsolidated sediments which have been transported by wind and water and have accumulated

along with calcareous ooze and shells in the lakes and seas and with the peat of the bogs and swamps. These sediments have been compacted and cemented together to form the coal-bearing strata often referred to as the "Coal Measures."

FIGURE 2. View of Dunkard topography from Switzer Schoolhouse (El. 1360!) looking northeastward.

Sequence of layers. In Switzerland Township, and in the rocks of equivalent age throughout most of the Appalachian area (Stout, 1931), there is an orderly repetition of the sequence of various kinds of strata. In the 870 feet of strata exposed in Switzerland Township, 35 cycles of deposition, more or less complete,

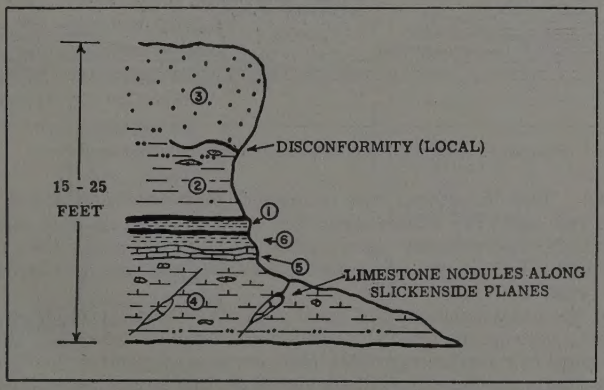

FIGURE 3. Diagrammatic sketch showing the members of an ideally developed cycle of deposition.

averaging 15 to 25 feet in thickness, illustrate the orderly sequence and recurrence of the various kinds of strata. An ideal cycle consists of six members. Beginning with the highest, these members are the following (fig. 3):

(6) Underclay (compacted clay)
(5) Limestone, light gray to dark gray, often nodular (calcium carbonate precipitated by plants and minute organisms, shell fragments, clay, silt)

(4) Shales, calcareous, dusky-red to dusky-yellow, non-bedded, with limestone nodules (compacted silt, clay, and calcareous mud)
(3) Sandstone, fine- to medium-grained, weathers moderate olive-brown
Disconformity (local)—break in deposition
(2) Roof shale, gray to dusky-red, well bedded (compacted silt and clay)
(1) Coal (altered plant remains) and/or carbonaceous shale

As should be expected, many local variations occur laterally even when the cycle is ideally developed, and in many instances one to three of the components may be missing or very poorly developed.

Clay. Nearly always associated with coals, the clays are best developed below the coals, although clay partings occur in the coal, and there are a few examples of a clay above the coal. The clays are normally gray in color and are similar to the shales below except that they are richer in alumina and contain less silt and sand.

In the past, it was thought that the clay represented an old soil which supported plant growth in the coal swamps. Although *stigmaria* (fossil roots) are found in some of the clays, the prevalent belief is that the silts and clay particles were deposited in the coal-forming swamps and were altered by the plants and decaying organic products.

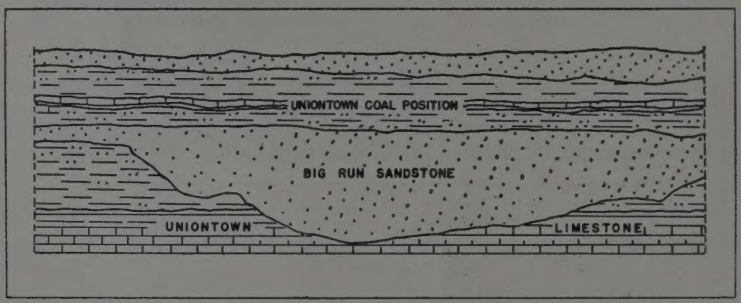

FIGURE 4. Sketch of a channel deposit of Big Run sandstone.

Limestone. The limestones are composed of hard thin-bedded layers with interbedded red and gray shales composed of clay minerals and calcareous ooze ($CaCO_3$), which was possibly precipitated largely by plant life, and varying amounts of silt. Incipiently developed limestone beds are nodular, more or less continuous beds.

Many of the limestones contain fossil remains of small animals, e.g., ostracods (crustaceans), gastropods (snails), pelecypods (clams), *spirorbis* (worm tubes), bone fragments, fish teeth, coprolites (fish excrement), and a few brackish-water brachiopods (lamp shells). It is believed that the faunal assemblage preserved in the limestones lived in fresh-water lakes lying just above sea level which were flooded occasionally by brackish water from the ocean.

Sandstone. Of the rock types, sandstone is the most resistant to the weathering and eroding processes; and wherever it is massively developed, falls, steep-walled cliffs, and amphitheaters in the heads of ravines add to the scenic beauty of the area. The remainder of the rocks decompose and disintegrate readily and unless protected by an overhanging cliff of sandstone, form gentle slopes covered with talus (rock debris) and soil.

Although the sandstones show many depositional features the irregularities at the base of the sandstone are most conspicuous. One of the most notable of the sandstones, the Big Run sandstone (fig. 4), thickens locally to 30 feet, replacing

the older rocks below. Outcropping on Ohio Route 7, one mile northeast of Powhatan Point, on Big Run, on Blair Run, and farther south along the Ohio River, the Big Run sandstone appears to have been deposited in an ancient stream channel whose course roughly paralleled the present Ohio River valley.

Roof shale. Resting directly on the coal or coal position is found a thin-bedded olive-gray to dusky-red shale, which on the outcrop is easily distinguished from the poorly bedded shale below the coal by its plate-like character. Toward the base of the roof shale and directly over the coal, the shale often contains well preserved fossil leaf and stem impressions.

GEOLOGIC TIME TABLE

ERAS ESTIMATED DURATION IN YEARS	PERIODS ESTIMATED DURATION IN YEARS	SERIES PRINCIPLE ROCK UNITS EXPOSED IN APPALACHIAN PLATEAU		THICKNESS OF SERIES EXPOSED IN SWITZERLAND TWP.
CENOZOIC 55 MILLION YEARS	QUATERNARY 2 MILLION YEARS TERTIARY 53 MILLION YEARS		NOT REPRESENTED IN THE APPALACHIAN REGION	60 FEET
MESOZOIC 106 MILLION YEARS	CRETACEOUS 55 MILLION YEARS JURASSIC 28 MILLION YEARS TRIASSIC 23 MILLION YEARS			
PALEOZOIC 314 MILLION YEARS	PERMIAN 33 MILLION YEARS	GREENE WASHINGTON	BELOW DRAINAGE IN SWITZERLAND TOWNSHIP	340 FEET 230 FEET
	PENNSYLVANIAN 42 MILLION YEARS	MONONGAHELA CONEMAUGH ALLEGHENY		300 FEET
	MISSISSIPPIAN 32 MILLION YEARS	POTTSVILLE		
	DEVONIAN 37 MILLION YEARS SILURIAN 22 MILLION YEARS ORDOVICIAN 79 MILLION YEARS CAMBRIAN 69 MILLION YEARS			
PRE-CAMBRIAN 1300 MILLION YEARS				

FIGURE 5. Geologic time table showing the principal units and thicknesses of rocks exposed in Switzerland Township.

Coal. In general, the area of the fresh-water lakes became swampy and was invaded by land-loving types of plants to form the verdant coal swamps of West Virginia, Pennsylvania, and Ohio.

The coals often vary in thickness laterally and are dependent on the thickness of the decaying plant debris and on the rapidity of deposition and the weight of the overlying sediments.

Of the 35 possible coal positions that exist in the exposed rock section of Switzerland Township, there are twelve bona fide coals. The thin streaks of

silty carbonaceous shales often replacing a coal or included in the coal represent finely divided organic debris from the coal swamp.

Summary. Clay, limestone, sandstone, shale, and coal are the rocks exposed in Switzerland Township and environs. They tell of widespread uniform conditions during which vast sheets of sediments were deposited laterally, but in which an ever-changing physical environment is evidenced in a few feet vertically.

SUMMARY OF THE GEOLOGIC HISTORY OF THE APPALACHIAN AREA

To have a clearer understanding of the rocks described in the preceding paragraphs, it is necessary to picture their relation to the names and the age of the major units of the geologic time table (fig. 5). The age of the major time units is based on the degree of disintegration of radioactive minerals, which is the most accurate means of determination available at the present time.

Except for the larger features, little is known of the life or landscape of the pre-Cambrian, which represents three-fourths of all geologic time. The history of the creation and evolution of the earth through this long period is buried beneath younger rocks on all the continents. In the area under discussion, the drill has never penetrated to a depth great enough to reach the basement rock.

From the Cambrian period through most of the Pennsylvanian period, the Appalachian region was occupied by a great seaway trending in a north-south direction. During most of this time, sediments from the land surrounding the trough were deposited in it by the streams flowing across the fringing land surfaces. A mountain range to the east and south, Appalachia, the eroded roots of which underlie the present coastal plain, supplied a great part of the sand, silt, and clay minerals which were lithified by cementation or compaction by the weight of the overlying sediments deposited later. With the subsidence of the trough increasing in proportion to the increased weight of the sediments nearer to the source area, Appalachia, greater thicknesses of rocks are present southeastward than underlie Switzerland Township.

Toward the end of the Mississippian period and continuing into the early Permian (the youngest recorded rocks in the Appalachian area) the seas which were so widespread in the earlier Paleozoic periods began to withdraw in uneven pulsations. A low swampy coastal plain bordered by deltas of the numerous northeastward-flowing, low-gradient, anastomosing streams dominated the landscape. Only occasionally thereafter did widespread incursions of shallow seas occur.

Vegetation flourished on the coastal plain and in the swamps, some of which were many thousands of square miles in area. After the accumulation of many feet of organic debris, viz., tree trunks, twigs, leaves, and decayed plants, chemical action altered the debris to peat which was then buried by vast sheets of sediments, sand, silt, and clay. The weight of the overlying sediments compacted the peat which, with the passage of time, developed into coal.

Sometime after the youngest rocks were deposited and at least partially lithified, during the Permian period, great horizontal forces were exerted from the southeast. The rocks nearest the orogenic center were folded and broken (faulted) forming the ancestral Appalachian mountains. The rocks farthest from the orogenic center were least affected by these stresses. This accounts for the essentially horizontal attitude of the strata in Switzerland Township and vicinity. Most of the structural features encountered in this area are not easily discernible by casual observation. Most of the apparent structures in the rocks are due to depositional irregularities and faulting and folding which occurred almost simultaneously with the sedimentation.

Approximately 160 million years have elapsed since the youngest exposed rocks were deposited, and during this time various erosional processes have been

at work. By the beginning of the Cretaceous period the land forms of the ancestral Appalachian mountains had been eroded to an almost level plain when warping of the mountain belt caused the streams to increase their gradient and quicken their erosional pace. At the beginning of the Tertiary period, the streams had again reduced the mountains and hills to a plain, remnants of which are still discernible as the Allegheny Plateau. With little or no folding, the entire area was once more uplifted, this time to a height of nearly one-half mile. The present

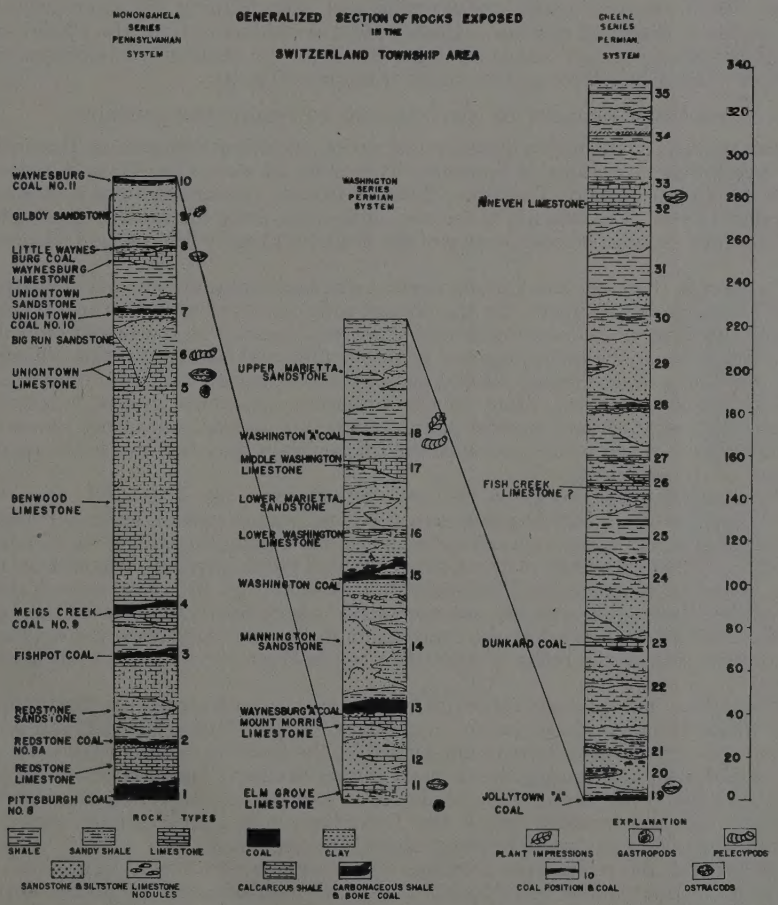

FIGURE 6. Generalized section of rocks exposed in the Switzerland Township area.

ruggedness of the Appalachian area results in the dissection of the Allegheny Plateau by the increased gradient of the streams due to the uplift, but evidence of the old plain is still preserved in the even crests of the high divides and knobs. By the beginning of the Tertiary period, almost 55 million years ago, North America had taken on a fairly modern appearance.

During the Pleistocene period, the occurrence of glaciation in northern Ohio and Pennsylvania was the last catastrophic event affecting the landscape in Switzerland Township and immediate environs. The glaciers blocked the north-flowing ancestral Ohio River, causing a huge lake to form in the valley and its tributaries. It is believed that this lake overflowed southward over a low divide at the narrows near New Martinsville, West Virginia. A new level of stream cutting and the influx of water from the melting glaciers to the north resulted in the present south-flowing Ohio River and its meandering and entrenched tributaries, which are continually undercutting and thus forming the steep walls of this maturely dissected plateau. Unconsolidated sediments from the glacial and recent periods, i.e., clays, sands, and gravels, form the channels, floodplains, and terraces of the Ohio River and its larger tributaries (fig. 9).

ECONOMIC GEOLOGY OF SWITZERLAND TOWNSHIP AND ENVIRONS

Introduction. The region under consideration, including Switzerland Township, and eastern eight sections of Sunsbury Township, Monroe County, and sections 7, 13, 19, and 25 of York Township, Belmont County, comprises an area of about 40 square miles. The area lies to the west of the axis of the Pittsburgh-Huntington coal basin in the southermost portion of the Belmont County field of the Pittsburgh coal.

In general, there are few deposits of great economic value except coal in Switzerland Township and vicinity. At the present time only the Pittsburgh coal is being mined, but some of the other coals may ultimately come to be considered economically important as the technologies of synthetic fuels and coal gasification advance. The possibility of developing oil and gas in the area is fair, but little exploration is being carried on now. Many of the limestones have been ground locally for agricultural purposes and as road metal, but no commercial use of the limestone is employed. In the future, a few of the thicker clays may find use in the manufacture of tile and brick.

Stratigraphy. The rocks of the area extend from the Pittsburgh coal, the lowest member of the Monongahela series, Pennsylvanian system, which is exposed on Cat Run in the north, upward to the rocks immediately overlying the Nineveh limestone, a high member of the Greene series, Permian system, exposed on the high ridges in south-central Switzerland Township (fig. 6). The named units above the Washington coal are not necessarily correlative with those of the type locality and will be revised at the completion of the field work being carried on at the present time in the rocks of equivalent age in West Virginia by Dr. Aureal T. Cross.

Structure. The geologic structure of this area is represented on the geologic map (plate I) by contours drawn on the base of the Pittsburgh coal. In areas where well or mine records were not available, the position of the Pittsburgh coal was reckoned by subtracting the normal interval from any higher outcropping key stratum. Since the driller's logs indicate a greater fluctuation of the interval between the key horizons below the Pittsburgh coal, modifications would be necessary to show the true features of the oil-bearing strata.

In general, the rocks have a comparatively simple structure. In addition to the gentle undulations of individual beds due to irregularities of the surface during deposition, a regional dip of 30 feet per mile in a southeast direction is probably due to a combination of down-warping of the trough to the east during deposition, with a subsequent regional flexure at a later time.

In the southeast, a structural terrace rises rapidly to form a ridge which trends northeast across the center of the area. In York Township, Belmont County, an anticlinal nose is shown which may be the southeastward extension of the Jacobsburg anticline, described by Stout in his unpublished report on the Monongahela series of Ohio.

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DIVISION OF GEOLOGICAL SURVEY
JOHN H. MELVIN, Chief

Scale

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Contour in

Base from U. S. Geologi

GEOLOGIC MAP OF SWITZERLAND TOWNSHIP AND IMMEDIATE ENVIRONS

P_n / P_g — Nineveh (Pn) Limestone in Greene Formation (Permian)

P_w — Washington Formation (Permian)

P_m — Monongahela Formation (Pennsylvanian)

500 — Structure Contours Drawn on Base of Pittsburgh Coal

BROKEN LINE INDICATES LACK OF DATA

GEOLOGY BY THOMAS ARKLE, JR.

DRAFTING BY RICHARD TURNER

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Oil and gas. In 1887 the first well in the area was drilled on Ackerson Run, Adams Township, north of the village of Cameron (Bownocker, 1903). The greatest drilling activity took place between 1887 and 1910, with only an occasional test well since that time. Although there is no record showing the actual number of wells or their production figures for this area, most of the oil in Monroe County was produced from Keener and Big Injun sands, and the available logs of this area indicate production from these sands. According to the residents, many wells came in at 25 barrels per day and were abandoned when production dropped to 10 barrels per day, because of the low price of oil. At the present time, the only producing wells are on Stillhouse and Johnson Runs.

The East Ohio Gas Company has made available a map which shows the location of approximately 100 wells for which only a few driller's logs are available at this time. At least 80 of these wells are grouped in small fields on the extreme eastern, southern, and western fringes of the area. They are generally located low in the valleys which permit drilling of lesser depths to pay sands.

Although the few scattered well logs are lacking in conciseness because the lens-like nature of the sands is not usually recognized by the driller, the information indicates that the area is one in which the prospector can hope to find some oil in one or more of several sandstones, all of which have produced in the past. The known producing sands are below the Pittsburgh coal, and in ascending order they are the Berea, the Big Injun, the Keener, and the Cow Run.

In the future the Berea sand may become an important source of oil, although few wells have penetrated it. The Berea sand is generally a shaly sandstone, 20 feet thick, resting 1600 to 1650 feet below the Pittsburgh coal, and since the Pittsburgh interval for all zones below the "Big Lime" is quite variable, the structure contour map on the Pittsburgh is not wholly applicable to the Berea sandstone. Several logs indicate that minor amounts of gas and oil have been produced from the Berea sand on Ackerson Run, sections 27 and 28, Sunsbury Township.

Usually the Keener sand, a 25-foot unit, rests 1100 to 1150 feet below the Pittsburgh coal and is generally separated from the Big Injun sand below, which is variable but attains a maximum thickness of 125 feet, by a thin shale unit. Both the Keener and Big Injun produce oil and appear to lose production in this area because of encroaching salt water.

Above the Keener sand is a limestone with a few sand zones, the driller's "Big Lime" sand, which is very irregular in thickness, varying from 25 to 100 feet. No record of production from the "Big Lime" is to be found in this area.

A sandstone correlative with either the Cow Run or Buell Run sand lies 450 feet below the Pittsburgh coal in section 30, Sunsbury Township. A resident here reported that in 1910 a field of seven wells was producing approximately 15 barrels of oil per well but was abandoned because of the low price of oil.

The relation of structure to the accumulation of oil in this area is not clear, and no attempt has been made to map the structure on the various sands, although the logs indicate that the sands are variable laterally, which may account for the accumulation of oil. William J. Millard of Bristow, Oklahoma, who has analyzed cores quantitatively for evidence of diffusion of oil pools in depth in this area, believes that oil accumulates where porosity and permeability are favorable regardless of structure. In a personal communication with the author in 1949 he stated, "I am of the opinion that untapped pools remain in the area under consideration where oil and gas will still be found in commercial quantities. Since the depth of drilling is not great and the gravity of the petroleum is light, the small independent producers should be attracted."

Coal. Of the thirty-five possible coal zones illustrated in figure 6, only eight can ever be considered as of potential economic importance in the Switzerland Township area. Below drainage, except along the lower reaches of Captina Creek

and Cat Run in York Township, most of the area is underlain by the lower Monongahela series coals, which are, in ascending order, the Pittsburgh (#8), the Redstone (#8A), the Fishpot, and the Meigs Creek (#9) (Bownocker and Dean, 1929).

The most valuable resource of the area is the Pittsburgh coal. The drill cores show it to vary from 4½ to 5½ feet of mineable coal which thins in the southwestern part of the area. The coal has been mined by the Powhatan Mining Company, Powhatan, Ohio, throughout most of the northeastern one-third of the area (fig. 7). Another opening was made by shaft at the Marcoll Mine, section 11, Switzerland Township, but it was abandoned following an explosion before any coal was removed. As far as the writer can determine, the remainder of the coal in this area is untouched.

Along the outcrop on Captina Creek and Cat Run, York Township, the Redstone and Fishpot coals have been used for domestic purposes in the past. Underlying most of the area are found the Redstone coal, composed of 1 to 2 feet of bone and coal, and the Fishpot coal, which varies from a mere streak to 3½ feet in

FIGURE 7. View from high in the hills above Powhatan Point showing the Powhatan mine tipple and the Ohio River in the foreground with the hills of West Virginia in the background.

thickness. On Captina Creek the Fishpot coal zone is 7′11″ thick, but it is made up of impure coal containing numerous clay partings and one sandstone parting. This coal is probably of the same character below drainage, but the drill core records are not detailed enough to show this. The partings and the ash content make the Fishpot valueless as a commercial fuel at the present time.

Above drainage on Captina Creek the Meigs Creek coal has been mined for domestic purposes. Below drainage the coal varies from 6 inches to 4½ feet, and it is present in all the drill cores available. In the vicinity of the Marcoll mine shaft, the core logs indicate four feet of coal. There is a possibility that this coal will be mined at this location in the future. The coals of the upper Monongahela and lower Washington series are above drainage in all the major valleys. They are usually multiple, thin-bedded, thick coal zones which, excepting the Washington coal, vary considerably in thickness laterally. In ascending order these coals are the Uniontown (#10), the Waynesburg (#11), the Waynesburg "A," and the Washington.

In the southern part of the area the Uniontown coal varies from 2 to 2½ feet and is split by two or three shale partings toward the base. It is being mined for domestic use on a small scale along Sunfish Creek and its north-heading tributaries. Low in the valleys throughout most of the northern portion of the area, surface outcrops show a few carbonaceous streaks in the Uniontown coal position.

In the area of this report, the Waynesburg coal is not mineable as a commercial fuel, but in the valleys tributary to the Ohio River it is of sufficient thickness to be mined for domestic uses. Just south of the Belmont-Monroe county line, it is one foot thick and rapidly thickens to 3 feet northward. Farther north in Belmont County the Waynesburg coal has been mined commercially.

FIGURE 8. View of Wm. Kindleberger's house, constructed from a high Greene series sandstone.

The Waynesburg "A" coal is present everywhere throughout the area, varying from 1 to 5 feet in thickness, but its high ash content and numerous partings limit its use as a commercial fuel. In general the maximum development of the Waynesburg "A" coal lies in a small oval-shaped field that trends northwestward from Nigger Run across the center of the area. In the past the coal was mined only for local purposes, but in the future a thick carbonaceous unit of this type may be useful as a synthetic fuel.

Throughout the area, the Washington coal is everywhere present in good development. It is generally divided into two benches by a clay parting which varies from 3 to 6 inches. In northeastern Switzerland Township, the parting thickens to 7 feet of clay and carbonaceous shale. The coal varies from 4 to 6 feet thick, but the lower bench, usually 1½ feet thick, is generally the best coal. The upper bench is usually comprised of interbedded shale and coal. The coal has been mined extensively for local use in the past and may be useful in the future in the synthetic fuels program.

Limestone. In the section exposed in Switzerland Township and environs there are numerous thin-bedded limestones. The principal ones in ascending order are the following: Fishpot, Benwood, and Uniontown limestones, which are thicker

units (10 to 50 feet); and Elm Grove, Mount Morris, Lower and Middle Washington, and a number of high thin multi-bedded limestones, including the Nineveh limestone toward the top of the Greene series, which are generally thinner units. Farmers report that they have used these limestones for agricultural purposes but with little success, since they are generally high in magnesium and low in calcium. Tests have been made of the Fishpot, Benwood, and Uniontown limestones at Armstrongs Mills, Washington Township, just north of the area, and the information at hand indicates that the uses to which the limestone of the Monongahela series may be put at the present time are few. Condit (1923) says:

> "None of the beds can be of much use for building. Most of the rock when burned for building lime gives an undesirable gray-blue color. The material does not seem promising for use in the manufacture of Portland cement."

In the rock section, the highest well-developed limestone, the Nineveh, lies just beneath the highest knobs in the eastern part of the area and is important in the formation of the fertile soil on which apples, corn, and alfalfa are grown. Tests to the south of the area of this report show the limestone to be 85 percent

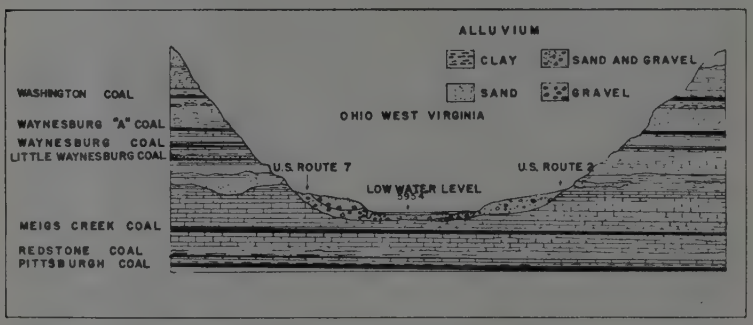

FIGURE 9. Cross-section of the Ohio River valley showing alluvium at Dam #14, north of Clarington, Ohio.

calcium carbonate and in certain zones to be as high as 95 percent. Although the rocks could be easily removed, few farmers have quarried the Nineveh limestone in recent years. Where suitably located, a number of the limestones have been used for road metal on state, county, and township roads.

Clay. Since most of the clays are thin or wanting, except that associated with the Washington coal, little interest in the clay has been shown. The thick clay above and below the Washington coal may be suitable as an aggregate for the manufacture of brick and tile in the future. Generally it is high in the hills at the valley mouths, and at present it is inaccessible at the points where it goes below drainage toward the valley heads. At the present time, the Marietta Silo Company, Marietta, Ohio, 60 miles south of the area of this report, has been quite successful in using a clay interpreted as being equivalent in the manufacture of their products.

Sandstone. The sandstones were important in the early construction of foundations, and one farmer, William Kindleberger, quarried one of the high Greene series sandstones for the construction of his house and barn (fig. 8). Deposits of sandstone throughout Switzerland Township are plentiful, but unless new uses for iron-stained, thinly laminated, friable sandstones are found, there is

little chance of their future development. Although there are no active sandstone quarries at the present time, the sandstones could be used as road metal on secondary roads.

Alluvium. The Ohio River floodplain and terraces bordering this area on the east are narrow but do contain clay, sand, and gravel. Bore holes at Dam #14 show that the floodplain of the river, including the various islands and bars, are composed of some boulders, gravel, coarse and fine sand, clay, and muds (fig. 9). In general, the sediments become coarser downward. Further prospecting would be necessary to show the areal extent of economically valuable deposits.

Alluvium is a reservoir for ground water and in the past has been extensively drilled for drinking water supplies. Since a ready source of water from the Ohio River and its larger tributaries is ever present in large quantities, the alluvium should be prospected for industrial water to be utilized by the rapidly expanding industries of the lower Ohio River valley.

ACKNOWLEDGMENTS

At the close of the summer field season two years ago, Mr. John H. Melvin, Chief of the Division of Geological Survey, Ohio Department of Natural Resources, suggested the preparation of this report. He and his staff have aided and encouraged the writer to its completion. In gathering the data, much valuable assistance was received from Dr. Aureal T. Cross, Coal Geologist, West Virginia Geological Survey, who also read the paper making many helpful suggestions. Special thanks are extended to the Powhatan Mining Company, Powhatan Point, Ohio, and to the residents of Switzerland Township for their aid and courtesy.

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A PRELIMINARY STUDY OF INDUSTRIAL POLLUTION IN THE CLEVELAND HARBOR AREA, OHIO.

I. PHYSICAL AND CHEMICAL RESULTS

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Cleveland, Ohio, is a highly industrialized city with a large proportion of its industrial plants located in the valley of the Cuyahoga River. Although plans have been drawn up to rectify the situation, to date the city for the most part has not constructed the necessary pumping stations to connect the valley sewers with the three city-operated sewage disposal plants. Therefore, in practically the entire valley, industrial effluents, raw domestic sewage, and street drainage empty directly into the river through numerous outlets. Thence they are carried into Cleveland Harbor and Lake Erie. Some industrial and domestic sewage is emptied into the river upstream, though of this the industrial pollution comes from immediate suburbs.

The largest industries in the Cuyahoga River valley are steel mills, which use water for cooling purposes, and which dump acid pickling wastes into the river. Effluents are also provided by oil refineries, chemical works, metal plants other than steel, etc. The Pucel Committee (1946) estimated that in 1944 there was a total of 171,812,100+ gallons per day of effluents dumped into the river, of which 822,850 were from raw domestic sewage, 33,863,650 from industrial process wastes and 136,247,500 from cooling water. Their figures did not include a number of large and small plants in the suburbs of Cleveland, and they were "restricted essentially to the larger users of water." Furthermore, their figures were based upon voluntary questionnaires, and there was no attempt to check on their accuracy. Of the reported industrial process wastes, which concern us most herein, 43.3 percent were from the metal industries and 53.2 percent from oil refineries.

In spite of general recognition by the public of gross pollution of the waters in the vicinity of Cleveland, there has been very little scientific investigation of the condition. Raymond Osburn, in 1926, directed a survey of the west end of Lake Erie in relation to sewage pollution, during which 5 stations were occupied in the Cleveland Harbor area. His reports (Osburn, 1926a, 1926b) dealt quantitatively with water temperature, pH, O_2 content, and bacteria. Rough qualitative analyses of bottom samples and plankton tows were also dealt with briefly. His reports exist only in mimeographed form.

Apparently the only printed reports of studies conducted in the Cleveland Harbor area deal with the effects of domestic sewage effluents. Thus, van Gieson (1942) studied the sewage pollution of Cleveland bathing beaches and Metcalf (1942) reported on some biological effects of a treated domestic sewage effluent.

Industrial and domestic sewage effluents were studied by the Pucel Committee (1946). Their mimeographed report constitutes the only published statement on industrial pollution in the area, aside from newspaper articles. The Pucel Committee, however, was not established to make a scientific investigation. In 1947 the Department of Health of the State of Ohio made a survey of industrial and municipal sewage wastes tributary to the Cuyahoga River. According to Mr. Bruce M. McDill, Engineer in Charge, Water Pollution Control, in a private communication: "The sewages and wastes were not actually evaluated by analyses and flow measurements. River analyses to show the effects of the pollution loads

were limited to dissolved oxygen and biochemical oxygen demand determinations. The results have not been published in form for general distribution."

In eastern Lake Erie, Fish *et al.* (1929) found that the effects of pollution were practically confined to the water in the vicinity of the shore. Dilution of the pollutants by the water of the open lake made pollution of the offshore water negligible, with no apparent deleterious effect upon the life therein. The results of Fish *et al.* were also reported in a briefer form by the New York Conservation Department (1929). In addition, however, in the latter publication the Niagara River and the several creeks tributary to Lake Erie and to the Niagara River in New York State were examined. Rush Creek in the vicinity of Buffalo was found heavily polluted with oil and with steel mill acid pickling liquor, similarly to the Cuyahoga River.

It was felt desirable to attempt to discover the extent and some of the effects of industrial pollution in the Cleveland Harbor area. To this end arrangements were made through the Franz Theodore Stone Institute of Hydrobiology, Put-in-Bay, Ohio, for the loan of equipment and for the granting of necessary funds. The Cleveland Harbor survey became part of a larger project under the direction of the Stone Institute, in which general pollution problems of northern Ohio waters tributary to Lake Erie were being studied. This project was supported by funds appropriated for the purpose by the State of Ohio.

It is a pleasure to acknowledge our debt to others for their contribution towards the success of the present study. The interest and encouragement of Dr. T. H. Langlois of the Franz Theodore Stone Institute and of Dr. F. W. Bacon of Western Reserve University made the project feasible in the first place. Our assistant, Mrs. Sally May Davis, performed yeoman duty in making the bulk of the chemical analyses. Mr. Edward Kirstead, Mr. Ervin W. Powell and Mr. Robert A. Woodmansee assisted from time to time on the field trips. To all of these we express our gratitude.

Field trips were attempted every two weeks throughout the year. Four of the proposed trips were cancelled on account of weather, illness, etc. Altogether 23 trips were taken between Sept. 15, 1950 and Sept. 30, 1951, as follows:

1. Sept. 15, 1950 (a preliminary survey trip, with few collections).
2. Sept. 29, 1950.
3. Oct. 13, 1950.
4. Oct. 27, 1950.
5. Nov. 11, 1950.
6. Dec. 9, 1950.
7. Dec. 21, 1950 (the trip was taken up and down the Cuyahoga River, because of ice conditions in the harbor).
8. Jan. 5, 1951.
9. Jan. 20, 1951.
10. Feb. 17, 1951 (only stations 1 and 2 occupied because of ice conditions).
11. Mar. 3, 1951.
12. Mar. 17, 1951.
13. April 6, 1951.
14. April 28, 1951.
15. May 12, 1951.
16. May 26, 1951.
17. June 23, 1951.
18. July 7, 1951.
19. July 21, 1951.
20. Aug. 4, 1951.
21. Sept. 3, 1951.
22. Sept. 14, 1951.
23. Sept. 30, 1951.

Nine stations were established in the Cleveland Harbor area, as follows:

Station 1. Under the railroad bridge near the mouth of the Cuyahoga River.
Station 2. Between W. Pierhead Light and E. Pierhead Light at the mouth of the jetties.
Station 3. Halfway between the jetties and the Intake Crib.
Station 4. At the Intake Crib.
Station 5. Off red bouy No. 2, off the foot of E. 17th St., inside the breakwater.
Station 6. Off the foot of E. 40th St., inside the breakwater.
Station 7. Off E. Entrance Light, inside the breakwater.
Station 8. Outside the breakwater, opposite Sta. 6.
Station 9. Outside the breakwater, opposite Sta. 5.

Figure 1 shows the locations of the regular stations.

On the trip of Dec. 21, 1950, ice conditions prevented leaving the Cuyahoga River, so a trip was made as far up the river as possible. In addition to regular station No. 1, the following stations were occupied in the river:

Station R1. Just north of the Harvard-Denison Bridge.
Station R2. About ¼ mi. downstream from the W. & L. E. R. R. Bridge, near Belt-Line Ave.
Station R3. At the head of navigation for large boats (near Campbell Ave., where the W. & L. E. and the N. & S. S. R. R. Bridges cross the river together).
Station R4. Under Clark Ave. Bridge.
Station R5. Just S. of the DuPont sulfuric acid plant (near Dille Ave.).

Figure 2 shows the location of the river stations.

On each trip, at each of the regular stations, observations and collections were made at the surface and at a depth of 6.5 meters (which is about one meter off the bottom at all stations except the deeper stations 3 and 4). The following observations and collections were made:

1. Observations:
   a. Temperature.
   b. pH.
   c. Qualitative test for ferrous iron (only at the most polluted stations).
2. Collections:
   a. A sample for the determination of oxygen.
   b. A sample for the determination of total iron. Used also to determine turbidity.
   c. A filtered sample for the determination of soluble iron. Used also to determine sulfate.
   d. A sample for the determination of centrifuge plankton.
   e. A sample taken by means of a Juday plankton trap.
   f. Qualitative net samples of the plankton, taken in the cleanest water visited on each particular trip.

In addition to the above, daily observations were made from the roof of the Standard Building for two periods during the year. By these observations the pattern of distribution of the gross pollution, indicated by water discoloration, could be determined and correlated with wind direction.

It has not been possible to make adequate analyses of the plankton samples to date, and so these will not be reported until later. All chemical analyses have been made. These will be reported in detail below.

PROCEDURES

Procedures used in making the chemical and physical observations and determinations were as follows:

Temperature was determined by means of a Negretti and Zambra reversing thermometer.

pH was determined in the field, at the time of taking the sample, by means of a Beckman pH meter, model M.

Ferrous ion (Fe^{++}) was determined qualitatively by means of a freshly-prepared solution of $K_3Fe(CN)_6$. Small quantities of the solution were poured into the surface water, or into samples of the deeper water, the appearance of Prussian blue being a positive test.

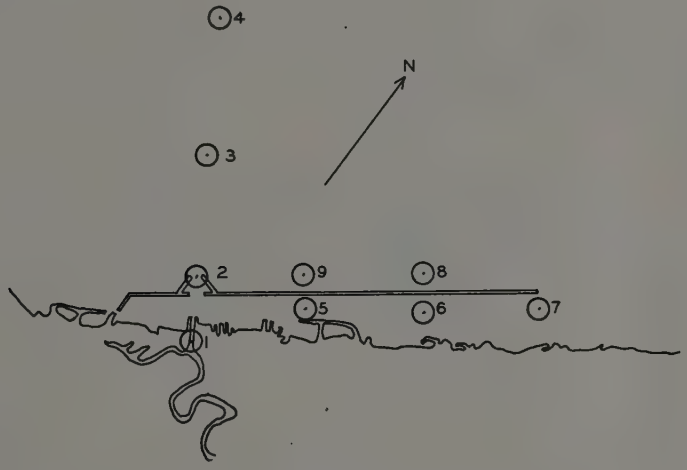

FIGURE 1. Map of the Cleveland Harbor area to show the location of the regular stations.

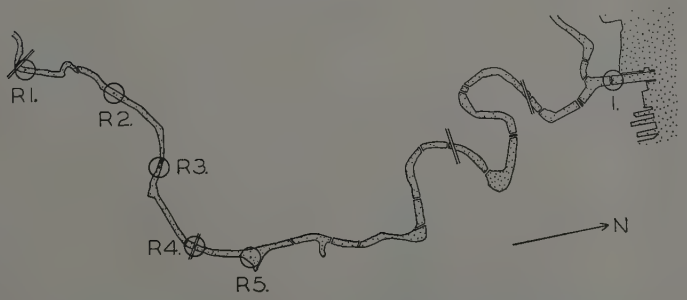

FIGURE 2. Map of the Cuyahoga River to just beyond the Harvard-Denison Bridge, showing the locations of the special river stations visited on Dec. 21, 1950.

Oxygen was determined by a modification of Winkler's method, whereby 4 ml of 85 percent H_3PO_4 were used as a substitute for the standard concentrated H_2SO_4, in order to prevent interference by the large quantities of Fe present in many of the samples. 250 ml samples were obtained for O_2 analyses.

Turbidity was determined as soon after the field trip as a 110 volt AC outlet became available. It was determined by use of a Hellige Turbidimeter, results being determined in terms of ppm of SiO_2.

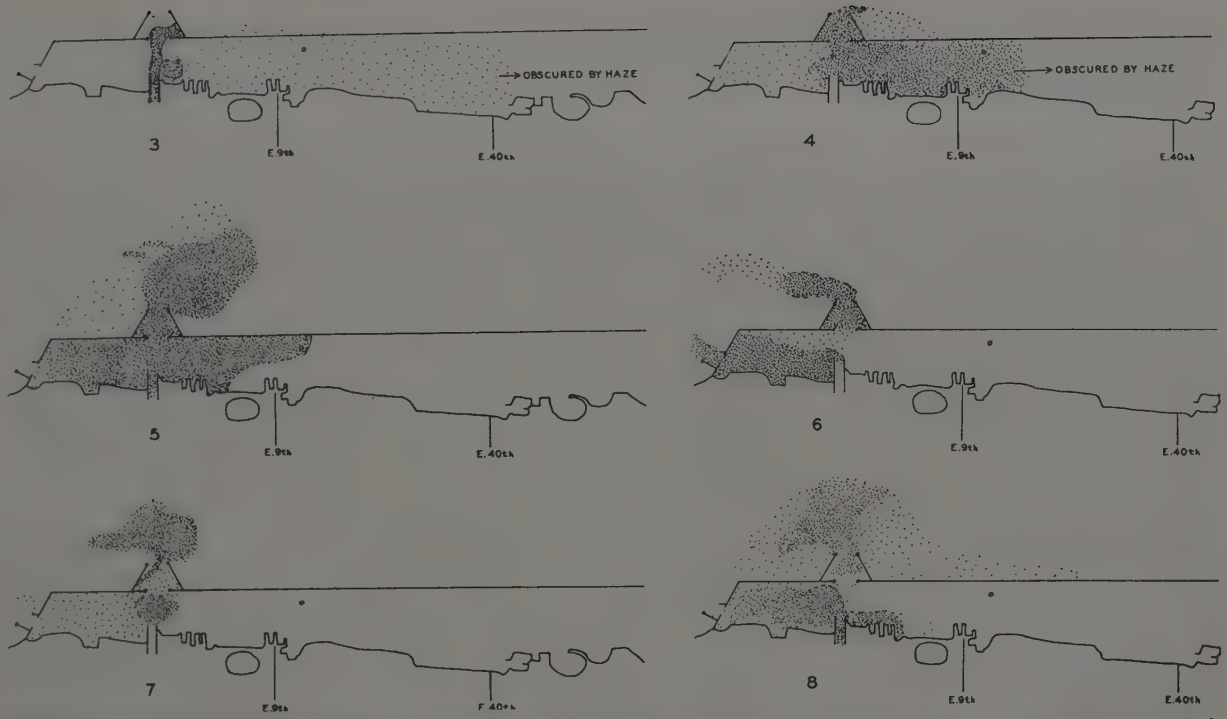

FIGURE 3. Distribution of discolored water in the vicinity of the Cleveland Harbor entrance on Aug. 8, 1951. The wind was NW and of moderate strength.
FIGURE 4. Same, on July 31, 1951. The wind was NW and of light strength.
FIGURE 5. Same, on Oct. 7, 1950. The wind was SW, moderate in strength.
FIGURE 6. Same, on July 17, 1951. The wind was strong and from the ENE.
FIGURE 7. Same, on July 24, 1951. The light wind was from the NE.
FIGURE 8. Same, on July 23, 1951. The wind was moderate, from the east.

Iron was determined colorimetrically by the thiocyanate method. Permanent standards were made, as described in *Standard Methods for the Examination of Water and Sewage.* Analyses were made for total iron, using an unfiltered sample of lake water, and for soluble iron by using a sample that had been filtered in the field at the time of collection. Particulate iron was calculated by taking the difference between total iron and soluble iron. The sample varied, as a rule, from 1 ml to 200 ml, depending upon the quantity of iron present. Samples of more than 100 ml were concentrated to 100 ml or less before analysis. 100 ml Nessler tubes were used for comparison with the standards.

Sulfate ion ($SO_4^=$) was determined by the analysis of a portion of the sample collected for the determination of soluble iron. The sample was refiltered before using. Analyses were made by use of the Hellige Turbidimeter, using the method described by the Hellige Company. Results are expressed in terms of ppm $SO_4^=$.

RESULTS

Thirty-four observations were made of the harbor area from the roof of the Standard Building.

Copperas ($FeSO_4 \cdot 7H_2O$) is a common industrial waste and appears as a pollutant in the pickling liquors from steel mills, as well as in several other industrial effluents. Consequently, large quantities are present in the effluents dumped into the Cuyahoga River. As Olson, Brust and Tressler (1941) have shown, the $FeSO_4$ hydrolizes and oxidizes when mixed in natural waters, thus removing free oxygen from the water, and producing a red-brown precipitate of $Fe(OH)_3$. This precipitate imparts a distinctive reddish-brown coloration to the water. Thus observations of gross pollution could be made and its distribution in space could be determined. Lesser degrees of pollution could not be detected in this manner. Wagner (1929) has observed a similar discoloration of Lake Erie water at the mouth of Rush Creek, near Buffalo.

As seen from the vantage point described, the discolored water remained for the most part within the confines of the harbor breakwater. However, some of it usually flowed out through the harbor entrance opposite the mouth of the Cuyahoga River, and occasionally also through the small entrance at the western end of the harbor. Discoloration was never apparent at the relatively distant eastern entrance.

Both inside and outside the breakwater the distribution of the discolored water was affected to a considerable degree by the direction and power of the wind. The prevailing water movement, however, was from west to east. Such a prevailing current also has been described by van Gieson (1942) in the vicinity of Cleveland's Easterly Sewage Disposal Plant. Towards the eastern end of the lake Fish *et al.* (1929) demonstrated it off Erie, Pa., and off Long Point on the Canadian side. They also pointed out the general easterly migration of creek mouths as an indication of the regular occurrence of such a current.

At times the line of demarcation between the discolored water and the more normal water would be very sharp whereas at other times the discoloration would gradually fade out and merge with the normal blue or green. Often a wind with a northerly component would prevent the discolored water from escaping through the main harbor entrance. The following are representative observations:

Figure 3 shows the distribution of discolored water on August 8, 1951, when there was a moderate NW wind. Discolored water did not escape through the main harbor entrance, though there was some evidence of a little discoloration outside the breakwater just to the east of the entrance. Heaviest discoloration was inside the harbor opposite the mouth of the river, with a slight easterly displacement in the inner half of the harbor. Lighter discoloration occurred inside the breakwater nearly as far as E 40th St., though a tongue of blue water just

inside the breakwater extended westward about half the distance between E 40th St. and E 9th St. Practically no discoloration extended westward from the river mouth.

Figure 4 shows the situation on July 31, 1951 when there was a light NW wind. Again, most of the discoloration extended to the east of the river mouth. Some heavy discoloration was extending out through the harbor entrance, and the easterly movement of the outside water mass is clearly shown.

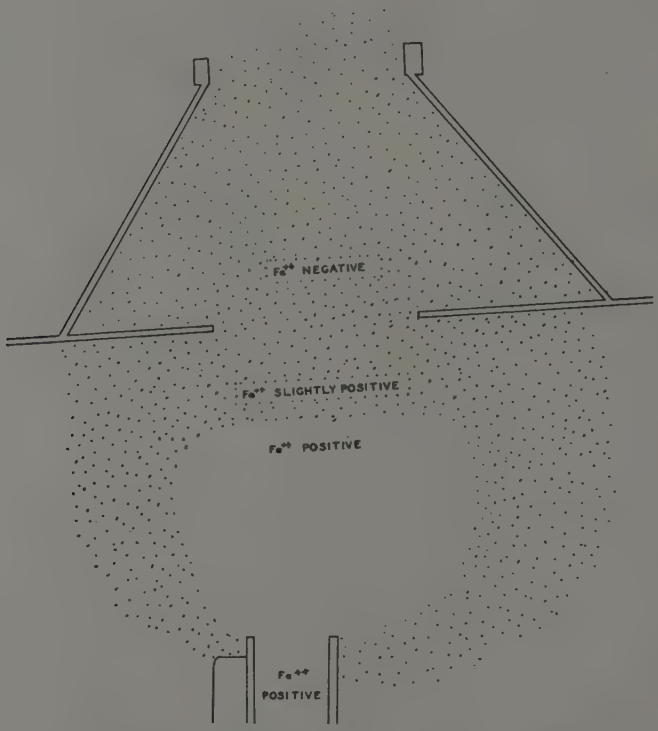

FIGURE 9. Distribution of discolored water and Fe^{++} at the mouth of the Cuyahoga River on Sept. 3, 1951.

Figure 5 shows the situation on Oct. 7, 1950 when there was a moderate SW wind. The discoloration extended farther out into the open lake than with northerly winds, but the easterly water movement was clear. Inside the breakwater the easterly movement was not clear.

Figure 6, on the other hand, shows the conditions on July 17, 1951, when there was a moderately strong ENE wind. Both inside and outside the breakwater the discolored water extended to the west, extruding through the westerly harbor entrance as well as through the main entrance. As shown by figures 7 and 8, however, all northeasterly and easterly winds did not produce such sharp results.

Thus figure 7 shows conditions on July 24, 1951 when there was a light NE wind and figure 8 shows conditions on July 23, 1951, when there was a moderate E wind. In both cases there was an evident easterly component of the water movement, both inside and outside the breakwater.

Closer observations were made of the distribution of discolored water near the mouth of the river on the regular field trips. It was usual for red water to flow from the mouth of the river into the harbor, but on Aug. 4 and Sept. 3, 1951, the water flowing from the river was relatively clear, while water in the harbor and out to station 2 and beyond was very turbid and red-brown. Figure 9 is drawn from a sketch made in the field on Sept. 3rd. The relatively clear river water gave strongly positive tests for Fe^{++}. The edge of the red water gave weakly positive tests, while farther away from the edge all tests were negative. On this date the water at station 1 gave no indication of any trace of oxygen. It appears evident that the ferrous iron (and other) pollution in the river was so heavy that all O_2 was exhausted in the surface waters so that the oxidation of Fe^{++} to Fe^{+++}, and the subsequent formation of $Fe(OH)_3$ precipitate, could not proceed until the river water had mixed with the relatively oxygen-rich harbor water. Subsequent to such mixture, oxidation and formation of precipitate proceeded rapidly.

The chemical and physical results are best shown in tabular form, except for the limited results of the field trip of Sept. 15, 1950. The main purpose of this preliminary trip was to explore the area and establish stations. No equipment had yet arrived with which to make observations or with which to test samples. Therefore only surface temperature readings were made, and centrifuge plankton samples were collected. The following temperatures were taken:

Station 5—20.65° C,
Station 6—20.15° C,
Station 7—20.15° C.

The results obtained on subsequent cruises are shown in table 1.

TABLE 1

Physical and chemical data for all stations on all trips

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2			Fe^{++}	Fe			$SO_4^{=}$ (ppm)
						ml/l	ppm	% sat		Tot	Sol	Part	
9–29–50	1	s	22.8	7.05	35 cm.*	0.0	0.0	0.0	Neg				
		d	18.2	7.50		2.2	3.0	31.9					
	2	s	18.6	7.30	100 cm.*	1.5	2.0	22.0	Neg				
		d	17.4	7.75		4.7	6.5	70.5					
	3	s	18.1	8.40	100 cm.*	6.4	8.9	95.3					
		d	18.8	8.40		6.4	8.8	96.4					
	4	s	18.5	8.71	314 cm.*	6.4	8.8	95.5					
		d	18.0	8.72		6.3	8.7	93.3					
	5	s	19.7	7.43	44 cm.*	3.4	4.7	52.5	Neg				
		d	17.9	7.83		4.5	6.2	66.0					
	6	s	18.7	8.38	200 cm.*	6.4	8.9	96.4					
		d	17.5	7.98		5.0	6.9	86.1					
	7	s	18.4	8.30	170 cm.*	5.9	8.2	88.4					
		d	17.6	8.31		6.1	8.4	89.3					
	8	s	18.2	8.40	200 cm.*	6.3	8.7	93.6					
		d	17.8	8.40		6.1	8.4	90.3					
10–13–50	1	s	23.8	6.78	90	0.0	0.0	0.0		13.0	5.0	8.0	2960
		d	16.3	7.30	53	4.2	6.0	60.6		3.0	0.8	2.2	
	5	s	15.0	7.78	38	5.6	8.0	77.8		1.5	0.4	1.1	42
		d	15.0	8.00	37	5.3	7.6	74.5		1.5	0.7	0.8	61
	6	s	13.9	8.15	40	6.1	8.8	83.8		0.6	0.4	0.2	34
		d	15.0	8.25	37	6.4	9.1	88.7		0.6	0.4	0.2	
	7	s	15.1	8.19	35	6.4	9.1	89.1		0.8	0.4	0.4	22
		d	15.2	8.19	35	6.5	9.2	90.7		0.6			

TABLE 1—(*Continued*)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2 ml/l	O_2 ppm	O_2 % sat	Fe^{++}	Fe Tot	Fe Sol	Fe Part	$SO_4^{=}$ (ppm)
10-27-50	1	s	20.3	7.05	88	0 0	0 0	0.0	Neg	15.0	11 3	3 7	81
	2	s	14.4	7.52	26	4.6	6.5	62 6	Neg	1.0	0 3	0.7	54
		d	14.3	7.78	20	4.7	6.7	64.6		0 8	0 3	0.5	54
	5	s	13.9	7 95	12	6 0	8.6	82.1		0.2	0.1	0.1	26
		d	13.7	7 85	17	5.5	7.8	74.5		0 3	0.1	0.2	32
	6	s	14.3	8.05	11	6.2	8 8	85 3		0 2	0.1	0 1	23
		d	14.3	8.02	13	6 1	8.7	83 9		0 2	0.1	0.1	25
	7	s	14.1	8 00	11	6.2	8.9	85 0		0 1			25
		d	14.1	8 12	13	6 1	8.7	83 5		0 1	0.1	?	21
	8	s	14.2	8.05	10	5.9	8.5	81.5		0 1	0.1	?	22
		d	14 1	8 10	10	6.1	8.7	83 5		0 2	0.1	0 1	26
	9	s	13 9	7.90	9	5.7	8.2	78 1		0 2	0 1	0 1	25
		d	14.0	7.91	10	5.4	7.7	73.8		0 2	0 1	0 1	35
11-11-50	1	s	18.2	6.99	57	0 0	0.0	0.0	Pos	15 0	15.0	0.0	288
		d	13.0	7.23	55	3.0	4.3	40.2	Sl. pos.	6 3	0.1	6 2	89
	2	s	10 0	8.72	34	7 0	10.0	87.7		0 4	0.1	0.3	18
		d	10 2										
	5	s	10 5	8.28	30	6.4	9.2	81.5		0.6	0.2	0 4	30
		d	10 5	8 60	34	6.1	8.7	77.0		0 8	0.2	0 6	
	6	s	10.5	8 42	26	6 6	9 5	83.9		0 4	0.1	0.3	38
		d	10 7	8.40	28	5.7	8.2	72.8		0.6	0.1	0.5	26
	7	s	10 6	8 50	29	6 6	9 4	83.5		0 3	0 1	0.2	18
		d	10 6	8.45	23	6.5	9.3	82.3		0 2	0.1	0 1	20
12- 9-50	1	s	3.0		100	6 8	9.7	71.5		4 8	1.5	3.3	161
		d	2.9		90	6 7	9.5	70.3		4 0	1.5	2.5	96
	2	s	2 1		53	8 0	11 4	82.5	Neg	0 5	0.2	0.3	27
		d	2 2		80	7.7	11 0	79 7		1.5	0.6	0.9	43
	5	s	2 2		57	7 6	10 8	78.4	Neg				60
		d	2 2		93	7.8	11.1	80.2		2 0	0.8	1 2	76
	6	s	2 2		60	8.0	11.4	82 2		0 8	0.5	0 3	33
		d	2.2		85	8.2	11.7	84 6		1 0	0.4	0 6	39
	7	s	2.2		80	8.0	11.4	82 6		0.8	0.4	0 4	71
		d	2.3		60	8 2	11 7	85 2		0.8	0.5	0 3	35
	8	s	2 0		78	8.4	12.0	86.6		0 8	0.6	0.2	36
		d	2.0		68	8.2	11.8	84 8		0.8	0.3	0.5	30
	9	s	2 2		60	8 4	12 0	86 8		0.5			37
		d	2 2		68	8 5	12 1	87 5		0.5	0.3	0.2	33
12-21-50	1	s	10 0	6 50		1.9	2 7	23 8	Pos.	15 0	7.0	8.0	186
		d	8 1	6 62		2.2	3.2	26.5	Sl. pos.	5 0	5 0	0.0	212
	R1	s	2 2	7.89		5 9	8.5	61 6	Pos	12 0	7 5	4 5	192
	R2	s	2 6	4.53		3.7	5.3	38.6		32 5	30 0	2 5	267
	R3	s	3 0	6 12		4 2	6.0	44 3	Pos	80 0	25.0	55 0	225
		12 ft.	3.0										
	R4	s	7.4	6.69		3 6	5.1	42 2		30 0	7.5	22 5	276
		15 ft.	7 4										
	R5	s	10.9	6.42		3.4	4.9	43.4		15.0	15.0	0.0	267
		15 ft.	10 8										
1- 5-51	1	s	4 4	7.76	103	6.7	9 6	73.4	Pos	5.0	2.5	2.5	98
		d	4 4	7 95	116	6 8	9 7	74 0	Sl. pos.	5 0	2.5	2.5	93
	2	s	0 6	8 38	70	8 7	12 4	86 2	Neg				39
		d	1 6	8 23	83	8 1	11 5	82 0		1 5	1.0	0.5	36
	3	s	0 6	8 48	14	8 6	12 3	85.1					18
		d	0 6	8 36	17	9 3	13.3	92 2		0 2	0.1	0.1	18
1-20-51	1	s	8 3	7 10	70	5 7	8 1	68 2	Pos	7.5	5.0	2 5	130
		d	8.3	7 15	62	5 7	8.1	68.0	Sl. pos.	8.0	3.8	4 2	98
	2	s	2 2	7 92	24	8 6	12 3	89.1	Neg	1.2	0.4	0 8	72
		d	2 2	7 92	17	8 7	12 4	89.9		0.8	0.5	0 3	30
	4	s	0 4	8 18	5	9 4	13.4	92.6		T	T	?	19
		d	0 4	8.10	12	9.3	13 3	91.6		T	T	?	20
	5	s	4 8	7 57	45	7 7	11 0	85.1	Neg	2.5	2.0	0 5	76
		d	4 7	7 75	47	7.7	11 1	85.3		3.0	2.0	1 0	
	6	s	3 7	7 71	52	5 6	8 0	60.2	Neg	1 8	1.5	0 3	58
		d	3 6	7 70	47	7.6	10 8	81.0					74
	7	s	1 6	7 94	37	7 8	11 2	79.8		0 6	0.4	0 2	27
		d	1 7	8 13	19	9 0	12 8	91.5		0 6	0.4	0 2	30
	8	s	1 1	8 22	21	9 0	12 9	92.0					25
		d	1 0	8 27	25	9 3	13 3	93.3		0 4	0.2	0 2	28
	9	s	1 0	8 28	25	9 1	13 1	91.9					
		d	1 0	8 38	19	9 4	13 4	94 1		0 4	0.2	0.2	26
2-17-51	1	s	4 8	7 14	83	6 5	9 3	69 2	Pos	10 0	3.5	6 5	106
		d	4 8		100	6 5	9 3	69 2		7 5	3 5	4 0	136
	2**	s	3 0	8 18	41	7 4	10 5	78 1	Neg	3 0	2.0	1 0	92
		d	4.0	8 38	47	7 2	10 3	77 8		3 5	2 0	1 5	95

TABLE 1—(*Continued*)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2			Fe^{++}	Fe			$SO_4^{=}$ (ppm)
						ml/1	ppm	% sat		Tot	Sol	Part	
3– 3–51	1	s	10.0	7.16	64	4.6	6.6	57.5	Pos	6.0	3.5	2.5	62
		d	10.0	7.22	57	4.7	6.7	58.3		7.5	5.0	2.5	76
	2	s	1.3	8.66	36	8.7	12.4	87.7		0.4	0.2	0.2	29
		d	1.3	8.66	38	8.1	11.6	82.0		7.5	0.4	7.1	30
	5	s	4.9	7.15	61	6.3	9.0	69.5		3.2	2.0	1.2	36
		d	5.2	7.48	69	6.1	8.8	68.3		3.0	2.0	1.0	102
	6	s	1.4	8.30	35	7.8	11.2	79.0		0.8	0.5	0.3	37
		d	3.0	7.96	38	7.0	10.1	74.3		1.8	1.0	0.8	31
	7	s	2.2	7.87	33	7.9	11.2	81.1		0.8	0.6	0.2	34
		d	2.3	8.14	33	7.4	10.6	76.9		1.0	0.8	0.2	38
	8	s	1.0	8.17	24	8.7	12.4	86.8		0.3	0.2	0.1	31
		d	1.0	8.22	24	8.6	12.3	86.4		0.3	0.2	0.1	26
	9	s	2.6	8.02	40	7.7	11.1	80.9		1.2	0.8	0.4	44
		d	2.7	8.21	42	7.7	11.0	80.8		1.0	0.8	0.2	32
3–17–51	1	s	8.0	7.04	57	5.8	8.3	69.6	Pos	6.3	3.8	2.5	75
		d	8.0	7.08	65	5.8	8.3	69.5		6.3	3.9	2.4	71
	2	s	2.6	7.49	43	8.4	12.0	88.0		1.0	0.5	0.5	34
		d	3.4	7.53	52	8.3	11.8	88.4		1.2	0.8	0.4	58
	3	s	2.2	8.53	38	8.9	12.8	92.6		0.4	0.2	0.2	31
		d	2.2	8.47	32	8.7	12.5	90.5		0.4	0.2	0.2	31
	4	s	2.0	8.59	25	9.0	12.9	93.3		0.2	T	0.2—	29
		d	2.0	8.48	22	9.2	13.1	94.3		0.2	T	0.2—	25
	5	s	4.0	7.68	52	7.4	11.6	79.2	Neg	2.0	1.2	0.8	75
		d	4.0	7.57	60	7.2	10.3	78.1		2.5	1.2	1.3	78
	6	s	3.3	7.73	38	8.2	11.7	87.0		1.5	0.8	0.7	57
		d	3.8	7.64	48	7.3	10.4	78.3		3.0	1.5	1.5	71
	7	s	3.8	7.92	36	8.5	12.2	91.8		0.9	0.6	0.3	52
		d	3.0	8.18	44	7.8	11.2	82.7		1.2	0.8	0.4	49
	8	s	2.5	8.20	41	8.9	12.7	92.9		0.5	0.3	0.2	64
		d	2.4	8.21	42	8.7	12.4	90.3		0.8	0.4	0.4	33
	9	s	2.4	8.17	42	8.8	12.5	91.1		0.6	0.2	0.4	31
		d	2.3	8.18	43	8.9	12.7	91.9		0.6	0.3	0.3	32
4– 6–51	1	s	11.4	7.22	64	3.3	4.7	42.5	Neg	7.5	2.5	5.0	138
		d	11.3	7.34	62	3.2	4.5	40.7		5.0	3.3	1.7	136
	2	s	4.8	8.03	50	4.9	7.0	53.7	Neg	2.5	1.0	1.5	47
		d	4.7	8.12	52	4.9	7.0	53.5		1.5	0.8	0.7	31
	3	s	3.3	8.53	24	5.0	7.2	53.5		0.2	0.1	0.1	22
		d	3.3	8.53	19	5.9	8.4	62.6		0.2	0.2	0.0	26
	4	s	2.4	8.76	27	5.5	7.8	56.8		0.2	0.1	0.1	
		d	2.5	8.75	16	4.9	7.0	51.1		0.2	0.1	0.1	21
	5	s	7.5	7.72	64	5.7	8.1	67.1	Neg	3.8	2.0	1.8	65
		d	5.3	7.74	57	5.9	8.5	66.1		3.0	2.0	1.0	65
	6	s	4.6	8.05	31	7.9	11.4	87.9	Neg	0.5	0.4	0.1	36
		d	4.8	7.90	45	7.2	10.3	79.7		1.5	1.0	0.5	38
	7	s	4.4	8.07	41	7.6	11.1	84.8		0.7	0.6	0.1	33
		d	4.3	8.08	41	4.9	7.1	53.9		0.8	0.6	0.2	38
	8	s	3.6	8.39	23	7.8	11.1	83.2		0.2	0.1	0.1	22
		d	3.5	8.40	26	7.0	10.1	75.5		0.3	0.2	0.1	22
	9	s	4.0	8.36	40	5.8	8.2	62.4		0.4	0.2	0.2	26
		d	3.9	8.25	31	7.4	10.6	79.8		0.4	0.3	0.1	22
4–28–51	1	s	17.2	6.72	83	0.0	0.0	0.0	Neg	7.5	3.0	4.5	122
		d	11.4	7.23	60	2.6	3.7	33.5		5.0	2.0	3.0	189
	2	s	8.0	8.08	38	8.2	11.7	98.6	Neg	0.8	0.4	0.4	29
		d	8.0	8.14	24	8.3	11.8	99.0		0.6	0.3	0.3	27
	3	s	7.0	8.43	21	9.4	13.3	109.6		0.3	0.1	0.2	24
		d	6.4	7.85	15	9.1	12.9	104.8		0.3	0.1	0.2	23
	4	s	6.1	8.36	37	9.4	13.3	107.1		0.2	0.2	0.0	23
		d	4.8	8.39	19	9.1	12.9	104.8		0.4	0.1	0.3	26
	5	s	11.4	7.55	28	4.1	5.9	53.2		3.3	1.5	1.8	68
		d	9.8	7.75	26	5.3	7.6	65.8		2.5	1.2	1.3	67
	6	s	9.4	7.75	24	6.3	9.0	78.0		1.0	0.6	0.4	40
		d	9.3	7.64	20	6.4	9.2	79.5		0.8	0.2	0.6	37
	7	s	9.0	7.92	28	7.4	10.6	90.8		0.6	0.2	0.4	35
		d	8.6	7.94	19	7.4	10.7	90.3		0.5	0.5	0.0	31
	8	s	7.8	8.29	23	8.4	12.1	100.2		0.4	0.3	0.1	26
		d	7.3	8.31	25	8.7	12.3	102.1		0.5	0.2	0.3	20
	9	s	7.4	8.25	28	7.4	10.6	87.3		0.6	0.6	0.0	34
		d	7.3	8.27	25	7.9	11.3	92.5		0.8	0.3	0.5	34
5–12–51	1	s	16.0	6.80	95	2.5	3.3	35.7	Neg	3.8	2.5	1.3	124
		d	16.9	6.91	88	2.3	3.3	33.8		3.8	2.5	1.3	111
	2	s	12.2	7.64	36	4.7	6.7	62.1	Neg	2.5	0.8	1.7	74
		d	11.8	8.02	54	6.2	8.8	80.6		2.5	0.6	1.9	54
	5	s	13.6	7.21	34	3.4	4.8	45.6		2.5	1.0	1.5	92
		d	12.5	7.40	34	5.0	7.2	66.8		2.5	1.2	1.3	68
	6	s	11.9	7.61	26	6.0	8.5	77.9		1.5	0.4	1.1	48
		d	11.6	7.63	22	6.5	9.3	84.7		1.3	0.2	1.1	31
	7	s	12.5	7.66	22	5.2	7.4	68.3		1.5	0.4	1.1	57
		d	11.3	7.98	22	6.9	7.8	88.9		1.0	0.2	0.8	30

TABLE 1—(*Continued*)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2			Fe^{++}	Fe			$SO_4^{=}$ (ppm)
						ml/l	ppm	% sat		Tot	Sol	Part	
5-26-51	1	s	23.6	3 98	44	0.0	0.0	0 0	Pos	15 0	9.0	6.0	66
	2	s	17.7	7 32	36	3 8	5.5	56.3	Neg	3.0	0 8	2.2	72
		d	14.5	8 00	15	4 5	6 4	61 7		0.3	0 2	0.1	27
	4	s	13.4	8.22	6	5 9	8 4	79 7		T	T	?	16
		d	13.1	8.20	6	7 4	10.6	99.7		0.1	T	0.1—	20
	5	s	17.2	7.16	18	3.7	5.3	52 2	Neg	3.0	1.3	1.7	68
		d	14.2	7.61	17	4.8	6 8	65 8		0 8	0 2	0.6	36
	6	s	15.8	7.30	14	4.4	6.3	61 9		1 0	0 4	0.6	31
		d	15.4	7.34	20	4.6	6 6	64 4		0 9	0 3	0.6	27
	7	s	15.8	7 49	18	4 5	6.5	64 0		0 8	0 2	0.6	38
		d	14.4	7 50	15	5 2	7 4	71 9		0 8	0 5	0 3	27
	8	s	14.4	8 18	18	7.1	10 2	98 0		0 4	0 1	0.3	19
		d	14.0	8 10	13	4.7	9 2	63 6		0.2	T	0.2—	21
	9	s	14.2	8.24	17	6.7	9.5	91 6		0.4	T	0 4 -	22
		d	13.9	8.22	15	6 7	9 5	90 9		0.5	T	0.5—	23
6-23-51	1	s	26 8	6 72	151	0.0	0.0	0 0	Pos	10.0	6.0	4 0	200
		d	22.5	6 90	165	0 2	0.3	3 2		12.5	4 0	8 5	150
	2	s	21.6	7 14	70	2.3	3.3	35 9	Neg	2 0	0 8	1 2	119
		d	20 3	7 60	14	3.6	5 3	55 9		0 8	0.2	0 6	30
	5	s	21.2	7 40	60	2.2	3 1	33.9	Neg	1.2	0.7	0.5	68
		d	19 8	7 61	23	3 2	4.7	49.3		1.0	0 3	0 7	31
	6	s	20 0	7 82	4	4 6	6 7	70.5		0.2	T	0 2—	25
		d	19 6	7 76	6	4 0	5.7	60 3		0.2	0 1	0.1	28
	7	s	20 2	7 84	3	4.6	6.7	71 6		T	T	?	23
		d	20 0	7 92	3	4 8	6.9	73.2		0.2	0 1	0.1	34
7- 7-51	1	s	25.2	7 04	87	0.0	0 0	0.0	Neg	6.0	3 0	3.0	103
		d	23 8	7 22	60	0 5	0 7	8.6		7 5	1 0	6.5	57
	2	s	21 8	7 80	26	4 1	5 8	64.9	Neg	1.0			41
		d	21 4	8 26	15	5 3	7 6	83.8					18
	3	s	21 0	8.34	3	5.7	8 1	88.7		T	T	?	36
		d	20 8	8 32	5	5 6	8.0	87.0		T			17
	4	s	21 0	8 37	3	5 7	8 1	89.1		T			26
		d	20.9	8 33	2	5 7	8.2	89.7		T			14
	5	s	22.5	7.56	21	3 0	4.2	47.5	Neg	1.0	0 4	0.6	17
		d	21 2	7.83	19	4 4	6.3	69.1			0 2		26
	6	s	22.2	7 78	13	4 2	6 1	67.8		0 4	0 3	0.1	26
		d	21.3	7 88	17	4 5	6.4	70.9			0 1		23
	7	s	22 1	7 90	13	4 4	6 3	70.1			0.1		32
		d	21 5	8 09	18	4 8	6 9	75.8		0 4	0 1	0.3	23
	8	s	22 2	8 22	18					0 1	0 1	0.0	20
		d	21 2	8.22	17	5 3	7 6	83.0		0 2	T	0.2—	20
	9	s	21.2	8 10	17	5 2	7.4	81.0		0 3	T	0.3—	23
		d	21 5	8 06	20	5.1	7 2	79.9		0.3	T	0.3—	18
7-21-51	1	s	28 4	6 92	90	0 0	0 0	0 0	Pos	12.5	7.5	5.0	129
		d	22 6	7.44	24	1.6	2.3	25 8	Neg	1 5	0 2	1.3	41
	2	s	22 7	7 70	19	3 2	4 6	52 1	Neg	0 8	0.3	0.5	50
		d	22 2	8 30	14	4.9	7 1	79.0		0 8	T	0.8—	17
	4	s	21 8	8 49	2	5 8	8 3	92 7		T	0.0	T	22
		d	21 8	8 39	1	5 8	8 2	91.6		0.0	0.0	0.0	17
	5	s	23 2	7 41	26	2 3	3 3	37 5	Neg	1 5	0.6	0.9	57
		d	21 6	7 73	13	3 2	4 5	50 3		0 8	0.3	0.5	33
	6	s	22 2	8 03	8	5 1	7 2	81 0		0 8	T	0.8—	10
		d	22 1	8 06	8	4 9	7 0	78 3		0 5	T	0.5—	23
	7	s	22 2	8 33	5	5 8	8 3	92 8					31
		d	21 6	8 29	5	3.2	4 6	52 1		0 1	T	0.1—	23
	8	s	22 0	8 41	3	5.8	8 3	92 0		T	0.0	T	23
		d	21 9	8 29	5	5 5	7 8	86 9		0 5	T	0.5—	22
	9	s	22 1	8 49	6	5 9	8 5	94 4		0 6	T	0 6—	23
	—	d	22 0	8 43	7	5 9	8 4	93 6		0.3	T	0.3—	20
8- 4-51	1	s	29.9	6 75	80	0 0	0 0	0 0	Pos	15.0	10 0	5 0	
		d	25.2	6 90	47	0 0	0 0	0 0	Sl. pos.	7 5	3 0	4 5	112
	2	s	24.7	7 18	20	1 9	2 6	31 0	Neg	3 0	0 8	2 2	84
		d	24.0	7 42	24	2 8	4 0	45 6		1 5	0 4	1 1	48
	5	s	24.6	7 50	12	3 7	5 2	59 0		0 6	T	0 6—	45
		d	23.6	7 45	17	3 9	5 6	64 5			0 2		42
	6	s	23 4	7 86	13	4 6	6 6	75 8		0 8	T	0 8—	24
		d	23.5	7 84	15	4 7	6 7	76 6		0 8	0 5	0 3	26
	7	s	23.5	7 62	38	4 6	6 5	74 9		1 5	0 2	1 3	29
		d	23.2	7 80	64	4 4	6 3	71 6		2 0	1 0	1 0	26
9- 3-51	1	s	28 3	6 88	45	0 0	0 0	0 0	Pos	15 0	7 5	7 5	164
		d	22 2	7 47	12	3 0	4 3	47 6	Neg	1 5	0 1	1 4	27
	2	s	22 8	7 29	15	2 0	2 8	31 9	Neg	2 0	0 6	1 4	82
		d	21 6	7 64	7	3 5	5 0	54 9		0 8	T	0 8—	25
	5	s	22 9	7 36	13	2 4	3 4	38 4	Neg	1 5	0 4	1 1	66
		d	19 8	7 50	10	1 4	2 0	21 9		0 6	T	0 6	19
	6	s	22 6	7 41	10	2 7	3 9	43 6		1 0	0 3	0 7	56
		d	21 0	7 63	6	3 5	4 9	54 2		0 2	T	0.2 -	23
	7	s	22 2	7 72	7	4 2	6 0	67 4		0 1	T	0 1—	26
		d	21 2	7 70	7	3 6	5 2	56 8		0 4	T	0 4 -	24

TABLE 1—(*Continued*)

Date	Sta	Depth	Temp (° C)	pH	Turbidity (ppm SiO_2)	O_2			Fe^{++}	Fe			$SO_4^{=}$ (ppm)
						ml/l	ppm	% sat		Tot	Sol	Part	
9–14–51	1	s	29.3	6.72	100	0.0	0.0	0.0	Pos	14.0	12.5	1.5	203
		d	23.7	7.17	45	1.6	2.2	25.6	Neg	6.5	1.1	5.4	74
	2	s	23.7	7.08	52	6.0	8.6	98.9	Neg	5.0	2.0	3.0	130
		d	20.8	7.64	7	5.0	7.2	78.6		0.5	0.3	0.2	31
	5	s	21.7	7.43	19	2.6	3.7	41.2	Neg	1.9	0.8	1.1	54
		d	21.0	7.69	8	3.5	5.0	55.3		0.5	0.3	0.2	41
	6	s	21.7	7.63	5	3.7	5.3	59.1		0.4	0.1	0.3	42
		d	21.1	7.65	7	3.4	4.8	53.0		0.4	0.1	0.3	45
	7	s	21.3	7.91	4	4.5	6.4	70.3		0.2	T	0.2—	46
		d	20.8	8.14	4	4.7	6.8	74.0		0.1	T	0.1—	31
	8	s	20.9	8.48	4	5.8	8.3	90.9		T	T	?	21
		d	20.7	8.42	4	5.7	8.1	88.2		T	0.0	T	26
	9	s	20.8	8.32	4	5.6	8.0	87.3					21
		d	20.6	8.26	5	5.6	8.0	87.3		T	T	?	25
9–30–51	1	s	21.5	7.70	100	0.0	0.0	0.0	Sl. pos.	13.5	6.5	7.0	178
		d	17.6	8.43	29	4.4	6.2	64.1	Neg	2.5	0.4	2.1	40
	2	s	17.7	7.62		4.4	6.3	64.8	Neg	2.0	0.8	1.2	54
		d	17.4	7.65		5.0	7.1	72.8		1.6	0.4	1.2	31
	3	s	17.3	8.08		6.1	8.7	89.2		T	T	?	22
		d	17.4	8.27		6.1	8.7	89.5		0.1	T	0.1—	27
	5	s	17.5	8.61		5.7	8.2	84.2	Neg	0.3	T	0.3—	37
		d	17.2	8.63	9	5.5	7.8	79.7		0.3	0.1	0.2	37
	6	s	17.4	8.72		5.7	8.2	83.8		0.3	T	0.3—	33
		d	17.5	8.72	8	5.7	8.2	84.0		0.1	T	0.1—	30
	7	s	17.5	8.70	13	5.9	8.4	86.2		T	T	?	25
		d	17.5	8.60		5.9	8.4	86.2		0.3	T	0.3—	31
	8	s	17.4							0.1	T	0.1—	23
		d	17.5	8.62		5.9	8.4	85.8		T	T	?	19
	9	s	17.3	8.19		6.1	8.7	89.2		T	T	?	22
		d	17.4	8.10		6.1	8.7	88.7		T	T	?	30

*Secchi disc readings.

** Ice conditions forced occupation of this station at a point about 100 meters south of the usual position.

DISCUSSION

In the Cleveland area, the major portion of the industrial effluents is dumped into the Cuyahoga River, though other portions are carried through municipal sewage disposal plants, and are dumped after treatment into Lake Erie or the river. The present report deals primarily with river effluents, though other effluents also had their effects.

The most highly polluted locality regularly studied was station 1. Here the iron content of the water was always much higher than at any other location, as was the content of $SO_4^{=}$. Fe^{++} occurred frequently, indicating proximity to the source of pollution. This ion never occurred at any other regular station. At times Fe^{++} was encountered just outside the mouth of the river also. Because of the consumption of oxygen by the ferrous ions, and by other oxygen-consuming agents as well, the water at station 1 was always low in oxygen content. Conditions were best on Jan. 5, 1951, when the O_2 was 73.4 percent of saturation. Out of the 22 times that oxygen was tested at this station, only five times was the figure greater than 50 percent of saturation, and 13 times there was no trace of oxygen at the surface, and sometimes at the bottom as well. Furthermore, the river water almost always gave off a strong odor, probably of phenols, etc. The pH at station 1 was always lower than elsewhere, but only once was it excessively low. The temperature was nearly always relatively high, due to the dumping of large quantities of cooling water. The maximum temperature was encountered on Aug. 4, 1951, when the surface water was 29.85° C. On this date the surface temperature at station 7, the clearest water visited, was 23.52° C. On Dec. 21, 1950, when ice conditions prevented exit from the river into the harbor, the surface temperature at station 1 was 9.95° C. The air temperature at the time was −12° C.

Figure 10 shows the seasonal distribution of temperatures at station 1. Note that the deeper water in the warmer months was much cooler than the water on the surface, whereas in the winter the surface and bottom temperatures were nearly or quite identical. It would seem that during the warm months there was a greater intrusion of lake water along the bottom.

Conditions for the existence of aquatic life were in general unsatisfactory at station 1. This is indicated by the results of those plankton analyses that have been completed, and also by the appearance of dead fish floating in the water on several occasions. On the trip of Sept. 3, 1951 thousands of minnows were dead or dying and had been washed up on the strand just to the west of the mouth of the river. On this day the water at this position gave off strong river odors.

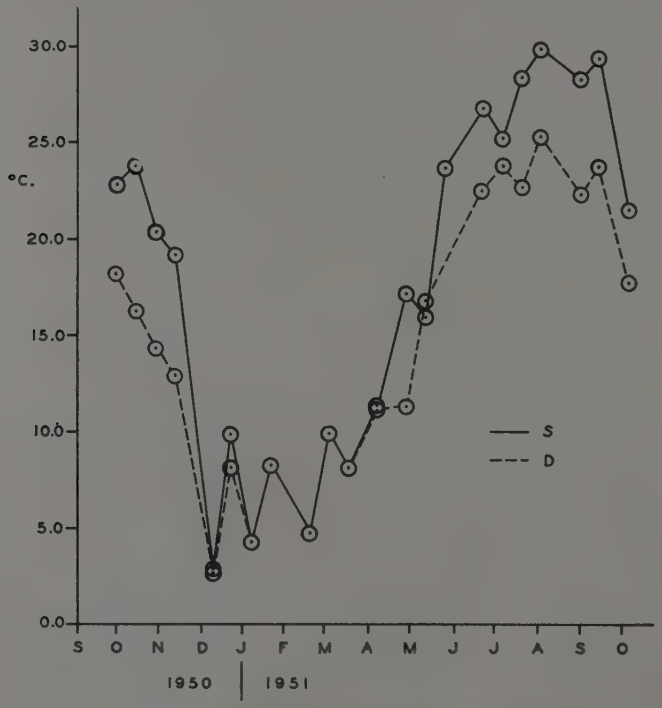

FIGURE 10. Seasonal distribution of temperatures at station 1.

A few crude experiments were performed in which living plankton Crustacea were mixed with water obtained from station 1. In one experiment the Crustacea were placed into three dishes. One dish contained river water, a second contained river water which had been thoroughly aerated, and a third was a control. The animals lived for some time in all three containers, but they survived much longer in the control than in either of the two experimental dishes.

Cutler (1929) found that industrial pollution in Rush Creek, near Buffalo, resulted in "an almost total absence of any form of animal or plant life" on the adjacent lake bottom, but that the very acid water near the mouth of the creek

supported an unusually rich growth of *Euglena* sp. "which the acidity appears to favor."

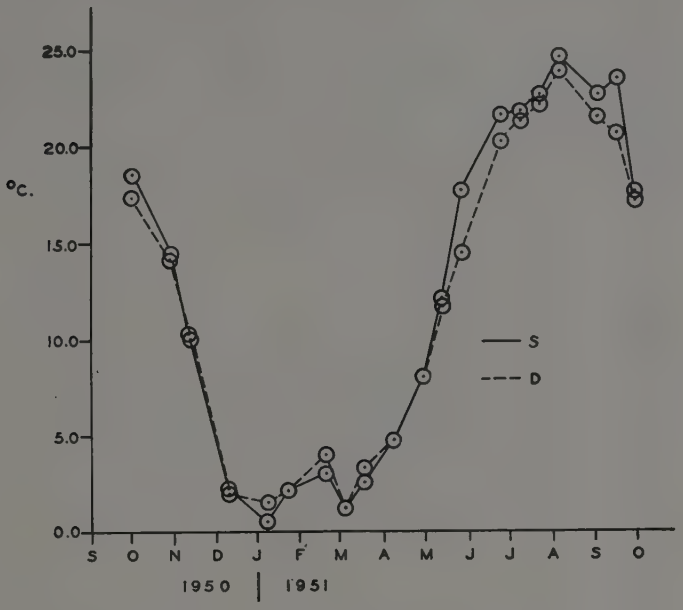

FIGURE 11. Seasonal distribution of temperatures at station 2.

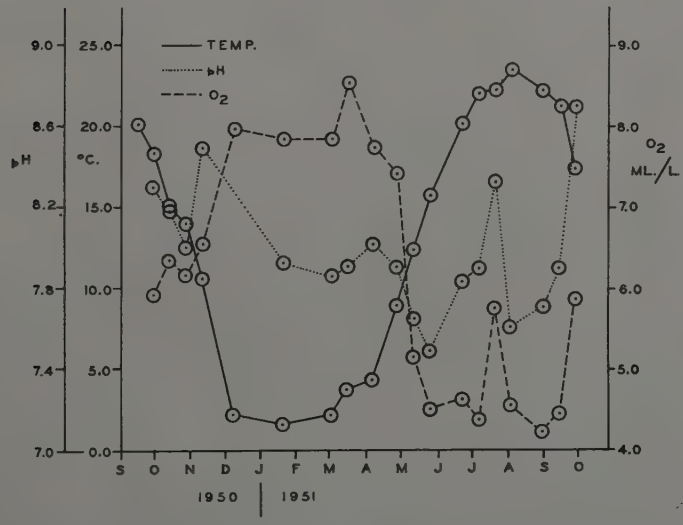

FIGURE 12. Seasonal distribution of temperature, O_2 and pH in the surface water at station 7.

Stations 2 and 5 were also highly influenced by the river effluents. Here again the iron content of the surface, and often (especially at station 5) the bottom water as well, was high. $SO_4^{=}$ was also relatively high. O_2 values usually were low, but oxygen was never entirely missing. At station 2 it was not unusual to find in the summer and fall months that the surface water was much warmer than that near the bottom. Similar temperature differences occurred also occasionally at station 5, but seldom at the other stations. Also, at station 2 the pH at the surface was lower than in the deep water while at the same time the surface water was much more turbid, this being obvious even to the naked eye as the samples were filtered. In the winter these conditions sometimes were reversed. It would appear that the relatively warm water flowing from the river in the summer and the fall flowed out over the cool water from the open lake, whereas in the winter the

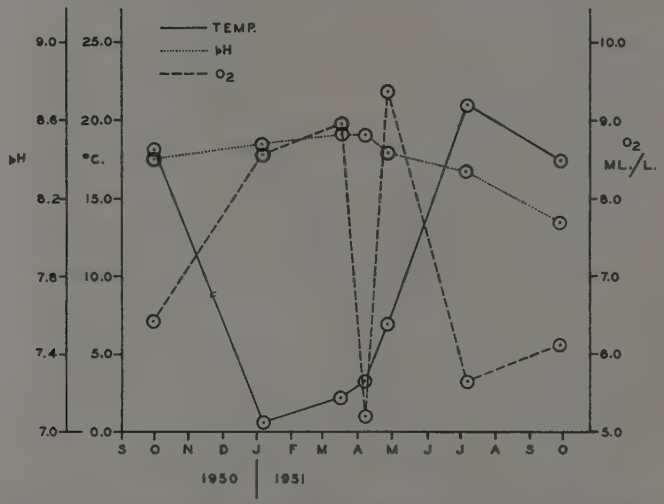

FIGURE 13. Seasonal distribution of temperature, O_2 and pH in the surface water at station 3.

relatively warm river water would be heavier than the cold lake water, and would sink. These relationships are shown clearly in figure 11, which shows the seasonal distribution of temperatures at station 2.

Conditions for the existence of resistant forms of aquatic life were rather favorable at station 2 and 5 though the high turbidity of the water would be sufficient to retard the life activities of algae. Examples of bottom muds obtained from stations 2 and 5 smelled very strongly, and that at station 5 was filled with a great deal of oil. At both locations there was a rich growth of annelid worms, along with other organisms, such as small pelecypods. These samples were collected after the regular series of trips reported upon herein, and are being studied by Dr. Harland B. Roney.

Stations 6 and 7, located in the harbor, were also somewhat polluted, but conditions were never extreme. Figure 12 shows the seasonal distribution of temperature, oxygen and pH at station 7. The great fluctuations of the pH undoubtedly were a reflection of the influence of inshore conditions and of pollution from the harbor. Stations 8 and 9 were located outside the breakwater. Open

lake conditions were approximated, especially at station 8. Stations 3 and 4 were located far out in the lake. Frequently weather conditions prevented visiting them. Both showed a very low content of iron, which at times amounted to only a trace (i. e., less than 0.1 mg Fe per liter of water), or even was undetectable. Sulfate ion, which would be less likely to precipitate out of the water than would the iron compounds, was somewhat higher, but this also averaged lower than at any other station. Turbidity was uniformly lower than at most other stations. Figure 13 shows the seasonal distribution of temperature, oxygen and pH at station

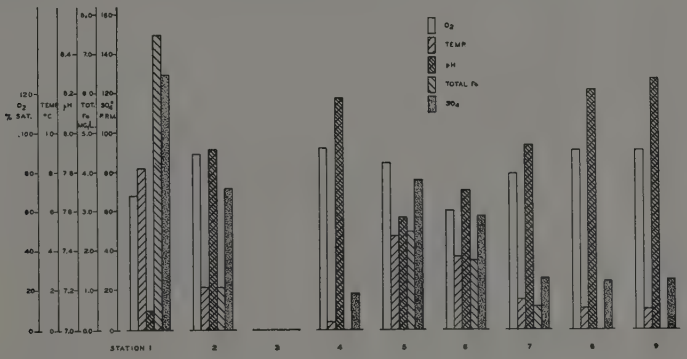

FIGURE 14. Distribution of O_2, temperature, pH, total Fe and $SO_4^=$ in the surface water in the Cleveland Harbor area on Jan. 20, 1951.

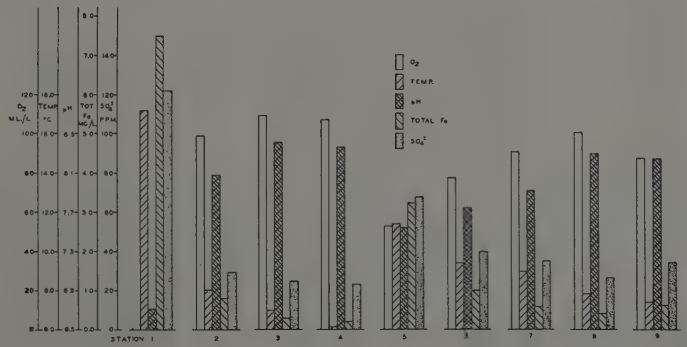

FIGURE 15. Distribution of O_2, temperature, pH, total Fe and $SO_4^=$ in the Cleveland Harbor area on April 28, 1951.

3. The sudden drop of O_2 on April 6 also occurred at station 4, and perhaps was caused by as yet undetected biological influences. At any rate, there was little evidence of any pollution.

There was some evidence that phytoplankton blooms appeared earlier at these outer stations than at the inner ones, and that the first large increase of zooplankton in the spring also occurred here. On the other hand, bottom samples obtained at stations 3 and 4 showed very little animal life compared to stations 2, 5 and 9.

Figures 14 and 15 show the distribution of oxygen, temperature, pH, total iron and $SO_4^=$ at the several stations on Jan. 20 and April 28, 1951 respectively. In the winter a high degree of pollution (shown by high Fe, high $SO_4^=$ and low pH)

caused less immediate depletion of O_2 than did similar conditions in the spring. However, it would appear that the O_2 depletion was merely delayed, and eventually it showed up clearly (station 6). In neither case was station 2 highly polluted.

CONCLUSIONS

It seems evident from the above analysis of the collected data that the industrial pollutants poured into the Cuyahoga River could be and undoubtedly are very deleterious to the existence of aquatic life in the river itself. These deleterious effects are certainly effective as far up the river as the steel mills in the vicinity of the Clark Avenue Bridge, and probably even far beyond the Harvard-Denison Bridge. Beyond the mouth of the river, aside from the unpleasant appearance and sickening odor of the water, there certainly are harmful effects from oil deposits in the bottom muds, the extent of which needs to be determined.

Another harmful result, extending over a considerable area, accrues from a reduction of photosynthesis, and hence of the productivity of the phytoplankton and of the attached algae, caused by high turbidities. The reduction in the oxygen content of the water also may be deleterious to animal life. Furthermore, it is evident that fish (especially game fish) are driven away, or poisoned by untested pollutant chemicals, such as the phenols. Cleveland oldtimers speak of the "good old days" in the early years of the present century when the best pike fishing in the vicinity was just inside the mouth of the Cuyahoga River, a location characterized today by nauseous odors, an oil-streaked surface, opaque water, and frequent complete lack of oxygen.

In small part these deleterious effects may be compensated for by the increased availability of plant nutrients in the raw and treated domestic sewage effluents that are poured into the Cuyahoga River by Cleveland and by villages and cities upstream from Cleveland. These questions can better be answered after analyses have been completed of the plankton samples and of the benthic organisms that were collected. It has been shown by Davis (1948) that copperas pollution may carry certain planktonic algae, such as diatoms, to the bottom muds, but that this process does not necessarily reduce the overall productivity of the water.

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REARRANGEMENT OF p, p'-DISUBSTITUTED BENZILS

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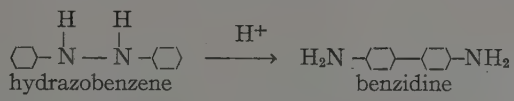
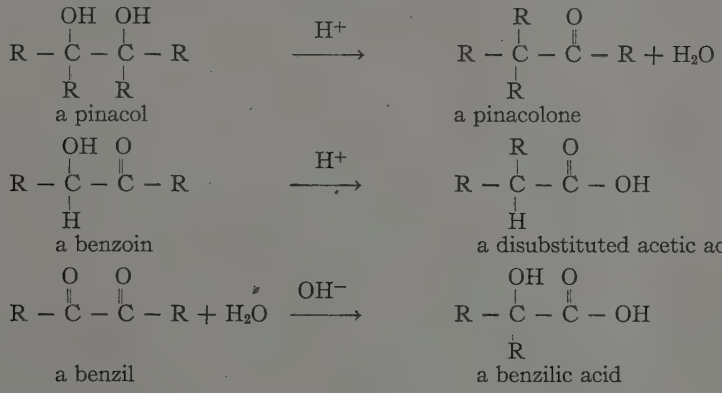
The term rearrangement, broadly speaking, refers to the shifting of atoms or radicals within a molecule, with or without the elimination of a simple molecule such as water. A new molecule is produced, containing essentially the same atoms as the original, but with a different arrangement. A good illustration is the conversion of hydrazobenzene to benzidine.



hydrazobenzene — benzidine

This change is induced by treating hydrazobenzene with a concentrated aqueous solution of hydrogen chloride.

An interesting group of rearrangements consists of the pinacol rearrangement, the benzoin rearrangement, and the benzilic acid rearrangement.



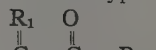
a pinacol — a pinacolone

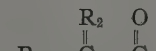
a benzoin — a disubstituted acetic acid

a benzil — a benzilic acid

These three rearrangements are similar in that they all involve the migration of a radical from one carbon to an adjacent carbon. They differ in the state of oxidation of the two carbon atoms between which the migration takes place.

A large number of examples of the pinacol rearrangement have been studied. Porter (1928) discusses several of these. R may represent either an aliphatic or an aromatic radical. Examples of the benzilic acid and benzoin rearrangements are less numerous and are restricted principally to compounds in which R represents an aromatic radical.

The pinacol rearrangement has been used as the basis of several studies of relative migratory aptitudes of different radicals. If a pinacol of the type is rearranged, the product may be either 

(if R_1 migrates), or  (R_2 migrates).

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Bachmann (1934) and others used this preferential migration to determine the relative migratory aptitudes of a large number of radicals, from which the following have been selected, in order of decreasing migratory aptitude, because these same radicals are studied in the present investigation:

p-anisyl,	$-C_6H_4-O-CH_3$
p-phenetyl,	$-C_6H_4-O-C_2H_5$
p-tolyl,	$-C_6H_4-CH_3$
p-cuminyl,	$-C_6H_4-CH(CH_3)_2$
phenyl,	$-C_6H_5$
p-chlorophenyl,	$-C_6H_4-Cl$

The benzoin and benzilic acid rearrangements are less well adapted to a study of migratory aptitudes, for in the benzoin rearrangement only one radical can migrate, and in the benzilic acid rearrangement the final product is the same regardless of which radical migrates. In these cases the relative migratory aptitude may be determined by subjecting different benzoins or benzils to identical conditions encouraging rearrangement, and determining the percent conversion to the rearrangement product. A study of this type was made with benzoins by James and Lyons (1938), resulting in the following series arranged in order of decreasing migratory aptitude:

phenyl > p-tolyl > p-cuminyl

It should be noted that this sequence is different from that obtained by the pinacol rearrangement.

In the case of the benzilic acid rearrangement, although several substituted benzils had been prepared and rearranged, no systematic comparison of their behavior had ever been made. The first substituted benzils that were studied were cuminil and anisil by Bösler (1881). Since then, perhaps a dozen others have been prepared. In most cases the investigator rearranged the benzil to the benzilic acid, being interested only in obtaining as high a yield as possible. The rearrangement was usually accomplished by refluxing the benzil with an alcohol-water solution of potassium hydroxide, and ordinarily resulted in yields of the rearrangement product of 80 to 95 percent.

That the ease of rearrangement is affected by the position of the substituting group on the benzene nucleus was shown by Schonberg and Keller (1923). A comparison of the rearrangements of 4, 4'-dimethoxybenzil (anisil), 3, 3'-dimethoxybenzil, and 2, 2'-dimethoxybenzil showed that the 4, 4' compound gave the greatest yield of the corresponding benzilic acid, the 3, 3' gave less, and the 2, 2' gave a rather low yield.

In the present study, several p, p'-disubstituted benzils have been prepared, and the relative migratory aptitudes of the substituted phenyl radicals has been found by determining the per cent conversion, under a standard set of conditions, to the corresponding benzilic acids.

EXPERIMENTAL WORK

Preparation of p, p'-disubstituted benzils

1. Benzil. $C_6H_5-C(=O)-C(=O)-C_6H_5$ Benzil was prepared by the oxidation of benzoin with nitric acid according to the directions of Adams (1921). After recrystallization from 95 percent alcohol it melted at 94.5°C. Literature, 95°.

2. Tolil. $CH_3-C_6H_4-C(=O)-C(=O)-C_6H_4-CH_3$ Tolualdehyde was condensed to toluoin as described by Stierlin (1889). This was oxidized to tolil with nitric acid.

After recrystallization from 95 percent alcohol it melted at 102–103°C. Literature, 105°.

3. *Cuminil.* $(CH_3)_2CH\text{-}C_6H_4\text{-}CO\text{-}CO\text{-}C_6H_4\text{-}CH(CH_3)_2$ Cuminic aldehyde was condensed to cuminoin according to the directions of Bösler (1881). The cuminoin was oxidized to cuminil with chromic acid as described by Widman (1881). After recrystallization from 95 percent alcohol it melted at 82–82.5°C. Literature, 83°.

4. *Anisil.* $CH_3O\text{-}C_6H_4\text{-}CO\text{-}CO\text{-}C_6H_4\text{-}OCH_3$ Anisic aldehyde was condensed to anisoin as described by Bösler (1881). The anisoin was oxidized by a mixture of copper acetate and ammonium nitrate in glacial acetic acid, according to Weiss and Appel (1948). Recrystallized from 80 percent acetic acid, the crystals had a melting point of 132°C. Literature, 132°.

5. *Phenetil.* $C_2H_5O\text{-}C_6H_4\text{-}CO\text{-}CO\text{-}C_6H_4\text{-}OC_2H_5$ Phenetole was condensed with oxalyl chloride in the presence of anhydrous aluminum chloride, as described by Schonberg and Kraemer (1922). It was recrystallized from glacial acetic acid, and melted at 148°C. Literature, 149°.

6. *p, p'-Dichlorobenzil.* $Cl\text{-}C_6H_4\text{-}CO\text{-}CO\text{-}C_6H_4\text{-}Cl$ The directions of Hodgson and Rosenberg (1930) were used to condense p, p'-dichlorobenzaldehyde to p, p'-dichlorobenzoin. Without attempting to isolate the benzoin, the mixture was oxidized with nitric acid diluted with acetic acid as suggested by Gomberg and Van Natta (1929). The p, p'-dichlorobenzil when recrystallized from acetic acid melted at 192–194°C. Literature, 195°.

Standardization of rearrangement conditions

After some experimentation with different methods of bringing about the rearrangement, it was decided that the classical solution of potassium hydroxide in a mixture of alcohol and water was the most suitable reagent. A series of trials was run to determine the percent conversion of benzil to benzilic acid at 25° C.

Samples each containing 2.10 g (0.01 mols) of benzil, 2.10 g (0.038 mols) of potassium hydroxide, 4.20 g of water and 4.20 g of alcohol were allowed to stand at 25°C for periods varying from 8 to 72 hours, with occasional shaking. During the course of the rearrangement a violet color appeared rather early in all samples. This color quickly darkened to a deep violet, and upon standing the color began to fade, until at about 50 hours it approached the yellow color present at the start of the experiment. At this stage, a cream-white precipitate was present, presumably potassium benzilate. At the end of the period of standing, water was added to dissolve the potassium benzilate. Filtration of this alkaline solution removed unchanged benzil and other non-acidic materials. The filtrate was then acidified with dilute hydrochloric acid, and the precipitated benzilic acid filtered onto a weighed sintered glass filter. After drying for 6 hours at 70–75°C, the filters were reweighed to obtain the weight of the benzilic acid (table 1). It should be mentioned that a slight precipitate often occurred just at the neutralization point and before the benzilic acid was precipitated. When this happened, it was removed by filtration before precipitating the benzilic acid.

Here and throughout the investigation samples were run in triplicate. Results were generally in good agreement, most of the figures falling within one percent of the average of the three trials. In all cases but one the melting point of the benzilic acid was 144° or higher, as compared to 150° for pure benzilic acid. Since the melting points were uniformly close to that of pure benzilic acid, further purification was not considered to be necessary.

A delicate test for benzilic acid is available. Even small amounts of benzilic acid impart an intense red color to concentrated sulfuric acid. This test was used to determine how completely the benzilic acid had been precipitated by acidification of the potassium benzilate solution. The precipitate of benzilic acid was filtered off, and a few drops of the filtrate were added to a few drops of concentrated sulfuric acid. Only a pale pink color appeared, so it was assumed that precipitation of benzilic acid was practically complete.

TABLE 1

Percent conversion of benzil to benzilic acid at 25° C.

Time (hours)	Average conversion	Time (hours)	Average conversion
8	30.3%	42	82.0%
12	42.0%	48	87.3%
24	69.2%	50	88.8%
30	74.1%	60	94.3%
32	76.4%	72	91.5%

Treatment of anisil, tolil, and phenetil with potassium hydroxide in the proportions described above was carried out for twenty-four hours at 25°C. Acidification of the reaction mixture did not give any precipitate of the expected disubstituted benzilic acids. A few drops, when added to concentrated sulfuric acid, did give an intense red color, showing that at least traces of the substituted benzilic acids had been formed.

Having failed to obtain any appreciable amount of rearrangement of substituted benzils at 25°, a series of samples was run at 40° with unsubstituted benzil. Other conditions were the same as before. Flasks containing the reaction mixture were suspended in a water bath with a stirrer maintained at a temperature of 40 ±1° by an immersion heater equipped with a rheostat. Each flask was removed and shaken occasionally during the heating period. On the basis of the results of these trials, 15 hours at 40° was selected for another trial with anisil and tolil. Just as before, however, no precipitate of the substituted benzilic acids was obtained, though the solution did cause an intense red color to form with concentrated sulfuric acid.

The temperature was then increased to 60° and a series of samples run with unsubstituted benzil. The results are shown in table 2. In these trials the amounts of alcohol, water, and potassium hydroxide were doubled, because experience had shown that the volume of liquid used before was so small that mixing by shaking was difficult.

On the basis of these results and our previous experience, 6 hours at 60°C was chosen for the next trials with substituted benzils. Under these conditions anisil rearranged to anisilic acid to the extent of 8.1 percent, and tolil to tolilic acid with a yield of 37.4 percent. Since these results were satisfactory, the same conditions were used for rearrangement of the other substituted benzils as described in detail below.

TABLE 2

Percent conversion of benzil to benzilic acid at 60° C.

Time (hours)	Average conversion
2	88.9%
6	87.0%
9	87.3%

Rearrangement of p, p'-disubstituted benzils

Reaction mixtures were made up in the following proportion: 0.01 mols of the substituted benzils, 4.20 g (0.075 mols) of potassium hydroxide, 8.40 g of water and 8.40 g of alcohol. These were well mixed in 125 ml Erlenmeyer flasks which were then suspended in a water bath maintained at 60 ± 1° for six hours. The flasks were removed and shaken occasionally. At the end of the heating period the flasks were removed from the bath, filtered to remove unchanged benzil, and the filtrate acidified with dilute hydrochloric acid until red to litmus paper. The benzilic acids which precipitated were filtered onto weighed sintered glass filters, washed, dried at 70–75° for 6 hours, and weighed.

1. *Tolil.* In the rearrangement of tolil to tolilic acid a dark brown solution was formed, which at the end of the heating period was diluted with water and filtered. The filtrate was acidified with dilute hydrochloric acid, forming a dark-brown gummy mass which solidified on standing. This was filtered onto a sintered glass funnel, washed, dried, and weighed. The melting point of the crude tolilic acid was found to be 120–125°. This was dissolved in dilute sodium carbonate solution and reprecipitated with hydrochloric acid, and then melted at 127–130°. The literature melting point (Gattermann, 1906) is 133–135°. An average yield of 37.4 percent was obtained.

2. *Cuminil.* The usual heating period was followed by acidification, giving a cream-white solid which melted at 110–113°. Dissolving in dilute sodium carbonate solution and reprecipitating gave a cream-white powder melting at 115–118°. Repeating the process gave a melting point of 118–119°. According to Bösler (1881) the melting point of cuminilic acid is 119–120°. The yield was 19.0 percent.

3. *Anisil.* Acidification of the reaction mixture in this case gave a cream-yellow precipitate. This was filtered, washed, dried and weighed. The average percent conversion of the three samples was 8.1 percent. The melting point of the crude acid was 149–153°C. Dissolving the crude acid in sodium carbonate solution and acidifying gave an almost white powder melting at 157–159°. A second recrystallization raised the melting point to 158–160°. According to Bösler (1881) the melting point of anisilic acid is 164°.

4. *Phenetil.* When phenetil was treated in the same manner, the amount of precipitate upon acidification was so slight that attempts to isolate it by filtration onto a sintered glass funnel resulted in loss of the sample. The addition of a few drops of the reaction mixture to a few milliliters of concentrated sulfuric acid resulted in the formation of an intense red color, showing that some rearrangement had taken place.

5. *p, p'-Dichlorobenzil.* When p, p'-dichlorobenzil was treated in the same way as the others, acidification produced a gummy mass. This was filtered, washed, dried, and weighed. The average percent conversion was 96.7. The crude material was dissolved in sodium carbonate solution and re-acidified. The product, when dry, melted at 159–162°. Again it was dissolved in alkali and acidified. The mass was still slightly gummy. After drying, a melting point of 158–165° was obtained. To get a reliable melting point further purification would no doubt have been necessary. Although this seemed to be the expected benzilic acid since it gave a red color with concentrated sulfuric acid and gave a positive Beilstein test for the presence of halogen, the melting point does not agree with that given by Montagne (1902) who claimed that p, p'-dichlorobenzilic acid melted at 101.75°.

SUMMARY AND CONCLUSIONS

The results of this investigation are summarized in table 3. On the basis of this data, it may be seen that the relative ease of migration of substituted radicals

in the benzilic acid rearrangement follows that of the benzoin rearrangement as determined by James (1938) rather than that of the pinacol rearrangement as

TABLE 3

Conversion of various benzils to the corresponding benzilic acids.

Benzil	Average conversion
Anisil	8.1%
Benzil	87.0%
Cuminil	19.0%
p, p'-Dichlorobenzil	96.7%
Phenetil	very small
Tolil	37.4%

determined by Bachmann (1934). The order of decreasing migraotry aptitudes in the three types is as follows:

Benzilic acid	*Benzoin*	*Pinacol*
p-chlorophenyl	phenyl	p-anisyl
phenyl	p-tolyl	p-phenetyl
p-tolyl	p-cuminyl	p-tolyl
p-cuminyl		p-cuminyl
p-anisyl		phenyl
p-phenetyl		p-chlorophenyl

These results are surprising since both the pinacol and the benzoin rearrangements are acid-catalyzed while the benzilic acid rearrangement is base-catalyzed. It should be pointed out, however, that the same method of determining percent conversion was used in the two series which agree with one another, while an entirely different method of determining migratory aptitudes was involved in the studies with the pinacol rearrangement.

Another interesting comparison may be made of this series with that of Kharasch and Reinmuth (1928) of decreasing electronegativity of radicals. In almost every case the migratory aptitude of the radicals in the benzilic acid rearrangement increases as the electronegativity decreases.

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THE MECHANISM OF THE IODINATION OF PHENOLS

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The transition of organic chemistry from an empirical science to a science having a well-established theoretical foundation has been slow and most incomplete. One of the main factors which has retarded this advance has been a lack of knowledge of the nature of organic reactions. Many theories have been proposed, but proofs of these theories are too often lacking or are quite unsatisfactory. This work was therefore planned to give information concerning the mechanism of one reaction; namely, the iodination of phenols in aqueous solutions.

Appreciable work on the iodination reaction has been done, and the conclusions concerning the mechanism of the reaction have been several. It has been proposed that the I_2 molecule, the I_3^- ion, the hypoiodous acid molecule, the I^+ ion, or the iodine atom is the substance directly responsible for the substitution of the iodine. With respect to the phenol both the undissociated molecule and the phenolate ion have been suggested as intermediates. It has been further proposed by several authors that the reaction may take place by means of a combination of several of these intermediates. For the most part the proofs of these proposals have not been well-founded, and in several instances they are highly conflicting.

For this paper there has been made a quantitative study of the effects of variation of pH, potassium iodide concentration, and temperature upon the iodination of 2, 4-dichlorophenol. In each individual study all the other factors, including ion concentrations, have been held as nearly constant as possible. The compound 2, 4-dichlorophenol was specifically chosen for study since only one halogen may be readily substituted.

DISCUSSION

The rate of iodination of 2, 4-dichlorophenol varies markedly with pH. As may be seen in table 1, the rate increases by a factor of about 42 as the pH is increased from 6.0 to 8.0. There are several possible explanations which are listed below.

TABLE 1

Variation of the calculated rate constants with pH and temperature. Starting conc. of I_2 and 2, 4-dichlorophenol = 0.00183 M. The average deviation for most of the rate values is between ±1% and ±3%.

pH	Added KI m/l	Temp. °C	k moles^{-1} sec^{-1}
6.0	0.008	25.6	0.076
6.4	0.008	25.6	0.263
7.0	0.008	25.6	0.99
7.4	0.008	25.6	1.87
8.0	0.008	25.6	3.18
8.0	0.012	25.6	1.09
8.0	0.008	33.5	6.6

1. Assume the phenolate ion is the active intermediate. Then, the variation in rate will depend on the actual concentration of the phenolate ion which in turn will depend on pH.

The ionization constant of phenol may be expressed:

$$K_i = \frac{[H^+]\ [\Phi O^-]}{[\Phi O H]} = \frac{[H^+]\ [\Phi O^-]}{a - x - [\Phi O^-]},$$

where K_i = ionization constant, $[\Phi OH]$ and $[\Phi O^-]$ are the phenol and phenolate ion concentrations and $a - x$ is the sum of the phenol and phenolate ion concentrations at any given time t.

Then

$$[\Phi O^-] = \frac{K_i\ (a - x)}{[H^+] + K_i}.$$

Substituting in the second order rate equation:

$$\frac{dx}{dt} = k\ [I_2]\ [\Phi O^-] = \frac{k\ K_i}{[H^+] + K_i}\ (a - x)^2,$$

where the starting concentrations of I_2 and total phenol are the same. The iodide ion concentration is assumed to remain constant. Tiessens (1931) has given the ionization constant for 2, 4-dichlorophenol as 3.1×10^{-8}. In like manner, the equilibrium $I^- + I_2 \rightleftarrows I_3^-$ will serve to reduce the rate of reaction, and the equation for the correction due to this equilibrium at a constant pH is:

$$\frac{dx}{dt} = \frac{k\ K_d}{[I^-] + K_d}\ (a - x)^2,$$

where $K_d = 1.4 \times 10^{-3}$ as given by Van Name and Brown (1917).

2. Assume hypoiodous acid is the active intermediate. The constant for the hydrolysis of iodine (Bray and Connolly, 1911) has been given as:

$$3 \times 10^{-13} = \frac{[H^+]\ [I^-]\ [HOI]}{[I_2]}.$$

Upon substituting the equation for the dissociation of the triiodide ion into the above equation we obtain:

$$[HOI] = \frac{4.2 \times 10^{-16}\ (a - x)}{[H^+]\ [I^-]\ ([I^-] + 1.4 \times 10^{-3})}.$$

At an effective iodide ion concentration of 0.0065 M and with $a - x$ equal to 0.00183 then:

$$[HOI] = \frac{1.5 \times 10^{-15}}{[H^+]},$$

$$\frac{dx}{dt} = k\ [HOI]\ [\Phi OH] = \frac{k \times 8 \times 10^{-12}}{[H^+]}\ (a - x)^2$$

There will be a change in the iodide ion concentration from the overall reaction:

$$I_3^- + C_6H_5O^- \rightarrow C_6H_4IO^- + H^+ + 2I^-.$$

The above equations will, however, be reasonably quantitative in accuracy.

3. Assume both the phenolate ion and hypoiodous acid are the reactants. Then, the rate of reaction will roughly vary inversely with the square of the hydrogen ion concentration.

In table 2 there are compared the calculated concentrations of the phenolate ion, the calculated concentrations of hypoiodous acid, and the observed reaction rate constants. In figures 1 and 2 these values are graphed. The plot of the phenolate ion concentrations against the observed rate constants is a straight line and indicates a direct proportion between these values. No such relationship exists between the hypoiodous acid concentrations and the rate constants. Therefore it may be concluded that the reaction takes place as a result of the interaction of the phenolate ion and the iodine molecule.

TABLE 2

Variation of the reaction rate with pH. A comparison of the calculated phenolate ion and hypoiodous acid concentrations with the observed rate constant values. Temperature 25.6°; added KI concentration 0.008 M; starting concentration of I_2 and 2, 4-dichlorophenol=0.00183 M.

pH	k m^{-1} sec^{-1}	Calc. Starting $[C_6H_3Cl_2O^-]$ m/l x 10^5	Calc. Starting [HOI] m/l x 10^8
6.0	0.076	5.5	1.5
6.4	0.263	13.2	3.7
7.0	0.99	44.	25.
7.4	1.87	80.	37.
8.0	3.18	138.	150.

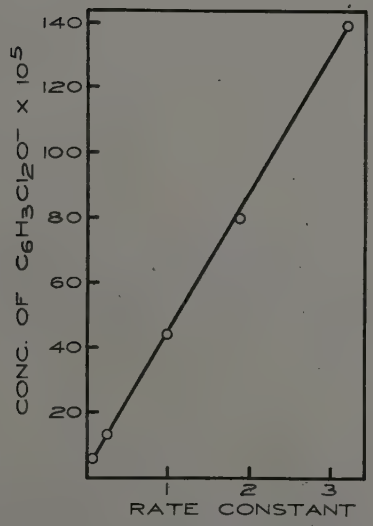


Figure 1

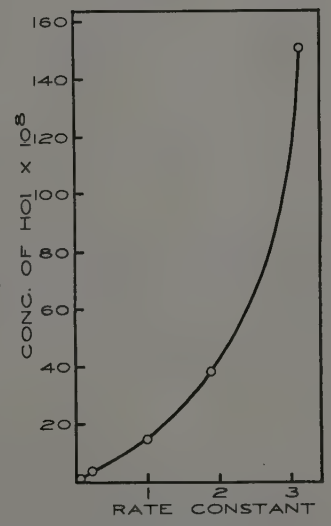


Figure 2

FIGURE 1. A graph showing the linear relationship of the starting concentration of the 2, 4-dichlorophenolate ion in moles per liter and the observed reaction rate constants in $moles^{-1}$ sec^{-1}.

FIGURE 2. A graph showing the lack of linear relationship between the starting hypoiodous acid concentration in moles per liter and the observed reaction rate constants in $moles^{-1}$ sec^{-1}.

Two series of experiments were run in which the iodide ion concentration was varied. Table 3 gives the observed rate and compares the calculated I_2 and HOI concentrations as predicted from the previously derived equations. It may be observed that neither equation quantitatively predicts the marked decrease in rate.

The activation energy has been roughly determined. The value from data in table 1 is 17 kcal/mole.

TABLE 3

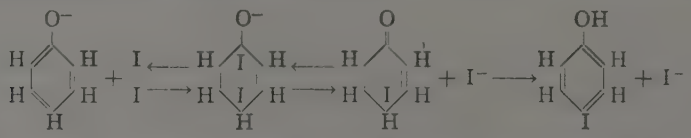
Variation of the reaction rate with iodide concentration. A comparison of the calculated concentrations of molecular iodine and hypoidous acid with the observed rate constant values. Temperature 25.6°; pH 8.0; starting concentration of I_2 and 2, 4-dichlorophenol = 0.00183 M.

Added KI m/l	Approx. Effective [I^-] m/l	k m^{-1} sec^{-1}	Calc. [HOI] m/l x 10^7	k/ /[HOI] x 10^6	Calc. [I_2] m/l x 10^4	k′ /[I_2] x 10^4
0.008	0.0065	3.18	1.5	2.1	3.2	1.0
0.012	0.0104	1.09	6.3	1.7	2.2	0.50

CONCLUSIONS

From the data concerning the variation of rate with pH it may be concluded the reaction of I_2 with phenols occurs by the direct reaction of the I_2 molecule and the phenolate ion.

The reason for the very marked effect of potassium iodide is not clear. Possibly another as yet undetermined equilibrium is involved. A possible mechanism is the following:



The equilibrium formation of the I^- in the second step would tend to be reversed by the presence of excess iodide ion. This equilibrium in addition to the $I_3^- \leftrightharpoons I^- + I_2$ equilibrium might explain the marked effect of the variation of iodide concentrations. This work with varying iodide ion concentrations clearly indicates that the mechanism of this reaction cannot be completely outlined from the data in this paper.

The low activation energy of 17 kcal. would seem to preclude equilibria of the nature

$$I_2 \leftrightharpoons 2\ I$$
$$\text{or } I_2 \leftrightharpoons I^+ + I^-,$$

since much larger amounts of energy are required to transform the I_2 molecule either to I atoms or I^+I^- ions. This value of 17 kcal mole undoubtedly does not represent the activation energy for the reaction, $I_2 + \Phi O^- \rightarrow$ products, since both pH and potassium iodide concentration affect the effective concentrations of the reactants. The activation energy should decrease with decreasing iodide ion concentrations and decrease with increasing pH. (This conclusion is based on unpublished work on the periodate-glycol reaction by Jay E. Taylor and B. Soldano.) Thus the true activation energy should be appreciably lower than the value given.

It is well known that ICl is an iodinating agent instead of a chlorinating agent. In view of the above evidence the most likely explanation is that the ICl molecule is polar (and not ionic) with the I atom having a partial plus charge. Upon attacking the phenolate ion the I is oriented to the ortho or para positions and the Cl to the carbon holding the O^- group. The Cl^- is then split out leaving the I substituted in the benzene ring.

Work is now being continued with this reaction, and it is hoped that a more complete view of the mechanism can be given in the near future.

EXPERIMENTAL

All chemicals used were of C.P. grade except the 2, 4-dichlorophenol which was recrystallized with much difficulty from a mixture of benzene and petroleum ether. It was necessary to carry out the recrystallization under anhydrous conditions as the phenol tended to absorb moisture from the atmosphere; this prevented the formation of crystals. It was kept in a dessicator.

The buffer solutions were made from varying amounts of hydrochloric acid and a constant amount of dipotassium hydrogen phosphate. The concentration of K_2HPO_4 added to each reaction mixture was equal to five times the concentration of phenol.

The 2, 4-dichlorophenol solution was made by weighing the solid.

The iodine solutions were standardized against standard sodium thiosulfate. A weight burette was used for greater accuracy and convenience.

To make a given run the equivalency of 1.814 ml or KI + I_2 solution (measured from a micro pipette) was determined. An equal quantity of the iodine solution was then placed in a small glass bucket. The bucket was set in a weighing bottle, and the bottle was then put into a constant temperature bath. An equivalent quantity of the phenol solution (about 18 ml) and the prescribed amount of buffer were placed in a 100 ml glass-stoppered flask which was then set in a constant temperature bath. After the reactants had come to temperature the iodine was dropped into the phenol solution and mixed. After a measured amount of time 3 ml of 5% phosphoric acid was added to stop the reaction, and the remaining iodine was titrated with standard thiosulfate.

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The New Physics. *Sir C. V. Raman.* Philosophical Library. New York. First Edition. 1951. 144 pp. $3.75.

This little volume results from a series of radio talks Professor Raman delivered to the Indian people some time between 1935 and the middle of World War II, judging from current references. The subjects covered are not those normally associated with the "new" physics but more the physics of everyday phenomena: light and color, soil physics, weather, crystal structure, a little astrophysics, and cosmic rays.

The level of presentation is adjusted for the general public and should not be considered a technical book. It gives some everyday sidelights of physics and observations of the author which would probably be of interest to the general public. However, the material given in the book would not add greatly to the reader's understanding of the basic fields of physics or to the present problems which currently occupy the time and efforts of physicists.

EDWARD S. FOSTER, JR.

SURFACE WATER MOVEMENT, WESTERN LAKE ERIE

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Controversy over the practicability of using drift bottles or cards for determining water movement has led to a long dispute. It is hoped that this paper will contribute some information toward the ending of the dispute. With the use of drift cards present findings show a close correlation between the wind and the surface current flow.

Since Harrington's (1895) first report on the currents of Lake Erie by using drift bottles, studies have been carried on intermittently. Olson (1951) used drift cards as a substitute for drift bottles, and the change was for the best, as drift cards are inexpensive and give greater accuracy to the surface flow because they are not exposed to the wind.

Olson's (1950) method of multiple release or putting cards out over a large area in a short period of time was varied by using a line release. This technique employed the principle of putting a solid line of cards several miles long in the lake. The longest line tried was 27 miles, on which over 500 cards were released or about one card every 260 feet. In the past two years over 3200 cards were released, with a 30% return.

TRIPS

Six line releases were made in 1950–51. Four show only one direction of flow while the other two show varying directions; in some cases opposing patterns were apparent.

When plotting the returns of the drift cards from many different locations the time adrift was correlated with the varying wind conditions over the period of time involved. Thus, if the reports from one trip showed one group of cards returned in 5 days from one location and another group of cards returned in 10 days from a different location it cannot be assumed that the same influences were exerted on both sets. Both sets of cards must be treated as individual groups under varying wind conditions during the period of time they were adrift.

Trip 1. On June 28, 1950, 290 cards were liberated in three groups, 60, 170 and 60 cards (fig. 1). The first returns were reported from Erieau, Ontario within 15 days; thereafter, cards were reported all along the north shore of Lake Erie as far as Long Point. About the first week in August cards were returned from the south side of Lake Erie near the city of Erie, Pa. and then down the shore as far as the southern edge of Buffalo. A distance of 250 miles was travelled in 38 days, a rate of 6.5 miles per day. This compares very favorably with the velocity measured in the open lake, using free floating vanes having an average of 6.2 miles per day. The wind during most of this period was from the west and southwest which is the prevailing wind direction over Lake Erie.

Trip 2. On July 22, 1950, 280 cards were liberated from Point Sheridan, Pelee Island, to Kingsville, Ontario (fig. 2). The first returns were from Kingsville on the 23rd of July, with cards from Point Pelee on the 25th and 26th of July. The wind was 6 to 8 mph from the south and east until the afternoon of the 24th. On the afternoon of the 24th the wind shifted to the northwest and increased from 12 to 20 mph.

From figure 2, it appears that the cards went across the channel, but, this is probably not the case. The cards undoubtedly went to the northwest but, having a longer distance to travel, were caught in the strong winds that came out of the northwest and thus were deposited on the tip of Point Pelee.

FIGURE 1.

FIGURE 2.

Trip 3. On August 4, 1950, 580 cards were released from the tip of Kelleys Island to Point Pelee, Ontario (fig. 3). The first returns came from Cedar Point and Rye Beach on August 7th. The wind was northwest 8 to 12 mph until the afternoon of the 6th and it then shifted to the northeast until the evening of the 7th. The second group of returns came from Marblehead and the south side of Kelleys Island, on the 10th and 12th. The wind on the night of the 7th shifted to the south and southwest until the 10th of August, the northeast wind probably accounts

for the shift of the cards to the west side of Kelleys Island and the cards found on Marblehead peninsula. The wind then shifting to the south accounts for the cards on the southwest side of Kelleys Island. From the 10th to the 14th the wind again shifted to the northeast. The cards moving to the northeast were related to the southwest wind, and were found after 12 to 18 days adrift.

FIGURE 3.

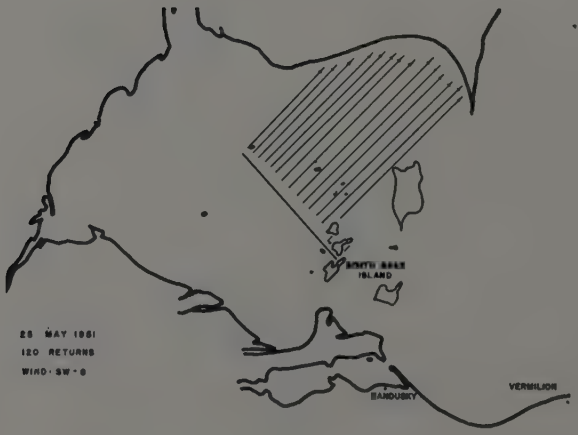

FIGURE 4.

Trip 4. On May 25, 1951, 350 cards were released in a straight line from Peach Point bar on South Bass Island to a point about 1 mile south of West Sister Island (fig. 4). The total distance was about 17 miles. The first returns were reported on the 27th of May. The wind was from the southwest 8 to 17 mph until the 28th of May. From the 28th to the 29th the wind shifted to the north-

west. About 5 cards were returned later from the south shore of Lake Erie, from Sandusky to Vermilion, Ohio. These cards were adrift 19 days and were caught in the winds from the northwest which followed the southwest blow.

Trip 5. The same number of cards were released on May 31, 1951 over the same route as of 6 days previous (fig. 5). The first returns were from the 7th to the

FIGURE 5.

FIGURE 6.

10th of June. On the 1st of June the wind was southwest, shifting to east on the 2nd. From the 4th to the 8th a northeast wind increased in velocity from 7 mph to 27 mph on the 7th and 8th of June, on the 9th the wind moved back to the east. There is little to say except that the returns show that the pattern of card movement is the complete reverse from the previous picture. There now appears to be a strong correlation between surface water movement and wind direction.

Trip 6. On October 1, 1951, 186 cards were released over the same route as Trips 4 and 5 (fig. 6). There were only 5 returns. This small number of returns is due to the lateness of the year and the fact that few people are on the beaches at that time of year. Nevertheless, the returns are interestingly different from the others. The first returns were from a point 8 miles east of Amherstburg, Ontario on the 8th of October. The wind was from the south until the 5th, and then moved around the compass until the 8th, and finally came from the southwest on the 9th, and stayed at this point for several days.

Three times cards were put out in the same manner along the same route and each time the cards landed in a different location. The wind direction in each case was in the direction of drift card movement. Drift bottles can move in an opposite direction to the wind with the current (Schmidt, 1913). Drift cards can also move against the wind with the current. However, surface currents cannot maintain their courses against the wind. The energy exerted by the wind upon the surface quickly overcomes the opposing force and changes the direction of flow, bringing it under wind control.

SUMMARY

Three important conclusions about the surface currents in western Lake Erie have been obtained by using drift cards.

1. Drift cards show surface water movement but no stable flow pattern can be established by using drift cards.

2. The drift cards averaged 6.5 miles per day which agrees with velocities measured in the open lake using free floating vanes.

3. There is a direct correlation between wind movement and surface flow in western Lake Erie. From indications of 3200 cards liberated, the surface water is wind controlled.

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1951. Plastic envelope substitute for drift bottles. Jour. Mar. Res., 10: 190–193.

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Ontario Birds. *L. L. Snyder.* Clarke, Irwin & Company Ltd. Toronto. 1951. First Edition. x+248 pp. Illustrated by T. M. Shortt. $4.50.

The author has written this book primarily for the amateur ornithologist, who desires to know something about the bird-life so commonly seen in northern and middle North America. He first introduces the reader to the subject by asking "What is a Bird?". The question is then carefully answered with comparisons made to the human being in so far as structure is concerned. Following this introduction, he discusses clearly some of the most fundamental aspects of bird distribution, and without difficulty some of the relationships which exist between birds and their habitats. A concise explanation of bird migration is then followed by a discussion on the classification of birds. A list of the birds of Ontario, with both common and scientific names appears in the chapter on classification. This list comprises a handy reference for bird watchers, of not only Ontario, but of adjacent areas. The remainder of the text, which makes up, for the most part, the major part of the book, presents the natural history of these different species of birds, in brief and interesting form.

This book will prove useful not only to the amateur ornithologist, but will be of considerable value to secondary and elementary school teachers as a source of useful information about our most common birds. In addition, it is recommended for colleges that try to explore the fields of knowledge beyond the strictly academic level. Mr. Snyder imparts to this book both his ability to tell about birds and his interest in the subject.

FRED H. GLENNY

TWO GENERA OF TETTIGELLIDAE PROPOSED BY MELICHAR

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Melichar (1924a) commenced a revision of the Cicadellidae, now known as the Tettigellidae, and this was continued during 1925a, 1926a, and 1932a, but, unfortunately, was never completed. In his key to the tribe Cicadellini (1926a: 340) he proposed 65 new genera. Of this number only 13 were described and had species assigned to them. China (1927d and 1938d) straightened out these new genera and published a list of the new genera with the genotype designations based on Melichar's unpublished manuscript. Evans (1947a) cataloged these genera and cited types of the 80 genera established by Melichar. Seventeen genera were based on new species which have never been described. Since these new species have not been published and these new genera have not been fully described, and since a portion of Melichar's collection has fallen into my hands, I deem it advisable to describe the new genera proposed and also the new species in an attempt to establish these new genera and species as far as possible.

The two genera that I want to establish in the present paper are *Luzoniella* Melichar (1926a: 341) and *Polisanella* Melichar (1926a: 343).

Luzoniana nom. nov.

pro *Luzoniella* Melichar (1926) Ann. Mus. Nat. Hungarici, 23: 341
nec *Luzoniella* Karny (1926) Treubia, 9: 185
Logotype *Luzoniella philippina* Evans (1947a: 162)
Luzoniella Melichar (1926a: 341) [Key, sine sp.]
China (1938d: 183) [Listed]
Neave (1939b: 1011) [Catalogued]
Evans (1947a: 162) [Catalogued]

The specimen before me agrees fairly well with the characters given in Melichar's key except Couplet B: Melichar (1926a: 341), "Hinterrand des Scheitels ganz, oder nur an den Seiten gekielt, häufig ± deutlich doppelt gebrochen." But since I have had trouble in determining other genera on the basis of this couplet, I assume that either the character is not a good one or my understanding of what Melichar intended to imply by these words is faulty.

Head broad, including the compound eyes, slightly broader than the pronotum; anterior margin of the crown broadly rounded, posterior margin deeply incised, the median third nearly straight; the whole posterior border distinctly and sharply carinate; muscular impressions of the postclypeus plainly visible on the crown; central area of the crown distinctly and broadly impressed, including the area of the ocelli; face large; with the postclypeus rather strongly inflated; no median impression, lateral muscular impressions short, not very deep; genae narrow; juga small, broadly rounded laterad; anteclypeus small. Pronotum large; anterior margin broadly curved; posterior lateral margins short; posterior margin broadly incised. Mesonotum with a distinct impressed line mediad with the usual impressed transverse line with two rather deeply impressed points anteriorly. Tegmina elongate, narrow; media connected with cubitus by three or more cross veins; the rest of the venation of the corium fairly regular; claval veins nearly parallel. Legs slender; hind tibiae elongate, slender with the inner anterior, the outer anterior, and the outer posterior margins set with heavy stout spines. Female genitalia elongate, strongly compressed.

Luzoniana philippina n. sp.

Figures 1–5

The general color of this species is light ochraceous with a tinge of greenish, with the tegmina shading to tawny and conspicuous color markings of fuscous on the head, mesonotum, and abdomen.

Crown about twice as broad as long; anterior margin broadly rounded; when viewed laterally, broadly rounded to the face; posterior margin broadly incised with a distinct sharp carina; deeply impressed just caudad of the ocelli; ocelli about twice as far from each other as from the compound eyes; postclypeus nearly as broad as long with the median area somewhat flattened, somewhat protuberant; antennae inserted in definite pits; margin of head above the antennal pits distinctly carinate; compound eyes rather large, protuberant; cheeks elongate, about twice as long as the dorsal margin, somewhat narrowed ventrally. Pronotum broad, flat; the anterior margin broadly curved, protruding anteriorally to about the middle of the compound eyes; lateral margins broadly incised; anterior lateral, posterior lateral, and posterior margins finely but distinctly carinate; posterior lateral margins nearly straight; posterior margin broadly, somewhat triangularly incised, with the posterior two-thirds fairly uniformly finely punctate, the anterior third deeply impressed without punctures. Mesonotum flat, transversely deeply incised just before the apical third, with two impressed points just anterior to the impressed line. Tegmina elongate, narrow, nearly parallel sided, with four apical and three ante-apical cells; cubital cell large, nearly twice as long as the apical cells and about twice as broad; four distinct cross veins between media and cubitus; claval veins not very distinct. Legs rather long and slender, the anterior tibiae with a row of setae on the posterior margin and a row of elongate slender spines on the anterior margin; posterior tibiae with the usual double row of stout spines on the lateral margins. Abdomen rather broad and short, lateral margins of the segments exposed beyond the tegmina. Female genitalia elongate, compressed. Pygofers more than four times as long as broad; last ventral segment twice as long as the penultimate, twice as broad as long, posterior margin broadly incised, broadly produced medianly.

General color of the head and pronotum ochraceous with a greenish tinge marked with fuscous as follows: lateral arcs on the crown and the face; a small elongate triangular spot at the anterior inner corners of the compound eyes; a small elongate oval spot at the anterior margin of the head on the median line; a small round spot on the median line of the face at about the level of the upper margin of the compound eyes; pronotum with three pairs of somewhat pustular spots behind the compound eyes; and mesonotum with three pairs of indistinct fuscous obconical marks on the anterior margin. Tegmina somewhat tawny. Abdomen dorsally with each segment with a broad basal fuscous fascia, separated from a narrower apical fuscous fascia by a narrow ochraceous fascia; extreme lateral margin, and the last dorsal segment ochraceous buff; ventrally the head, thorax, and legs chiefly ochraceous with some fuscous shading; abdomen ventrally chiefly fuscous with the genital segments greenish ochraceous.

Length to apex of tegmina 8.6 mm.

Holotype female, Northern Luzon.

Polisanella Melichar

Polisanella Melichar (1926a: 343) [Key, sine sp.]

Logotype *Polisanella bakeri* Evans (1947a: 164)

This genus may be characterized as having a rather narrow head with the crown somewhat protuberant, distinctly separated from the face by a sharp carina; pronotum broad, the anterior margin distinctly and continuously rounded from the shoulders; tegmina elongate with the venation fairly regular, fine and indistinct.

EXPLANATION OF FIGURES IN PLATE

1. *Luzoniana philippina* n. sp., dorsal view of head and thorax.
2. *Luzoniana philippina* n. sp., frontal view of head.
3. *Luzoniana philippina* n. sp., lateral view of head and thorax.
4. *Luzoniana philippina* n. sp., left tegmen.
5. *Luzoniana philippina* n. sp., ventral view of female genitalia.
6. *Polisanella bakeri* n. sp., dorsal view of head and thorax.
7. *Polisanella bakeri* n. sp., frontal view of head.
8. *Polisanella bakeri* n. sp., lateral view of head and thorax.
9. *Polisanella bakeri* n. sp., left tegmen.
10. *Polisanella bakeri* n. sp., ventral view of female genitalia.

Illustrations by Marjorie C. Hales.

Fig. 1

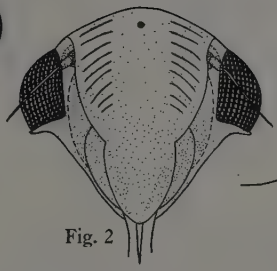

Fig. 2

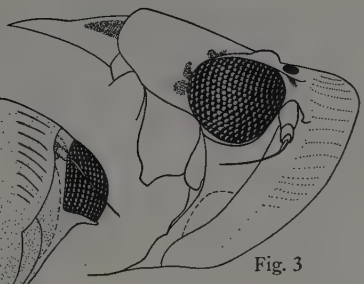

Fig. 3

Fig. 4

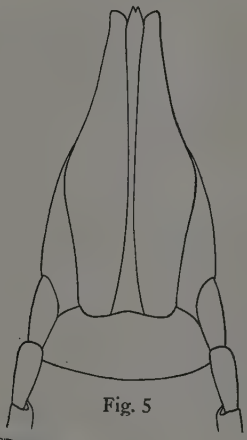

Fig. 5

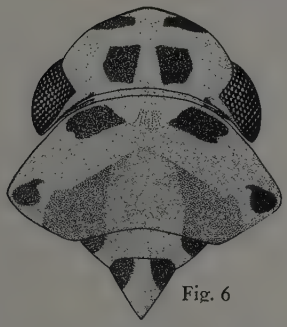

Fig. 6

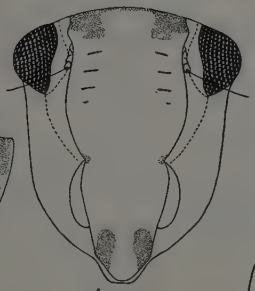

Fig. 7

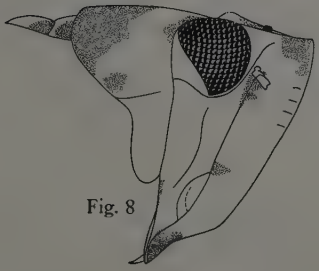

Fig. 8

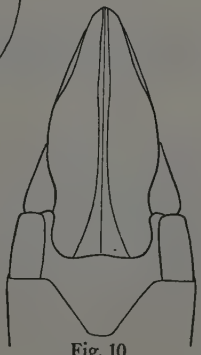

Fig. 10

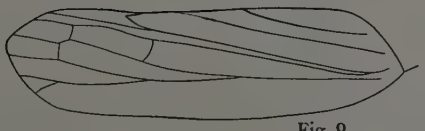

Fig. 9

Head narrow; crown flat, anterior and posterior margins broadly curved, sharply carinate; postclypeus elongate, nearly parallel sided on the dorsal two-thirds, then sharply narrowed. Pronotum broad; anterior margin broadly curved; the anterior lateral margins blending with the anterior margin; posterior lateral margins elongate, straight; posterior margin nearly straight; surface flat, the anterior third finely punctate; the posterior two-thirds finely rugulose. Mesonotum small with a distinct impressed line at the middle; general surface rugulose. Tegmina narrow, the margins nearly parallel; basal area finely punctate, coriaceous; venation regular, indistinct. Legs slender, anterior and intermediate legs short; posterior tibiae longer than the femora with two rows of stout spines on the outer margins.

Polisanella bakeri n. sp.

Figures 6–10

Crown nearly twice as broad as long; the whole surface smooth; anterior and posterior carinae fine but sharp; ocelli about equi-distant from each other and the eyes. Pronotum about twice as broad as long; the anterior third rather smooth; posterior two-thirds finely but rather uniformly rugulose; whole surface rather flat. Mesonotum about one and one-half times as broad as long; whole surface rather flat with a deep impressed line on the anterior third. Tegmina opaque, the basal third rather deeply but finely punctate. Female genitalia with the last ventral segment deeply and broadly incised; the anterior margin broadly v-shaped.

General color light ochraceous buff, shading to ochraceous buff and heavily marked with black as follows: two relatively large, elongate spots on the anterior margin of the crown, connected by a narrow fuscous fascia and continued onto the dorsal margin of the face as a pair of very irregular spots; two large quadrate spots on the crown near the posterior border and including the ocelli; two large irregular spots on the pronotum behind the eyes and on the posterior lateral margins of the pronotum near the shoulders; posterior half of the pronotum fuscous; mesonotum with the anterior lateral angles with large triangular black spots, and behind the impressed line two smaller triangular spots. Face marked with blackish below the dorsal margin, a continuation of the anterior spots on the crown; about four of the lateral arcs fuscous; a small blackish spot and elongate blackish stripe laterad of the postclypeus below the antennae; a small black spot laterad of the postclypeus where the suture separating the anteclypeus from the juga and the suture separating the juga from the cheeks meet the postclypeal suture; two pairs of small spots on the lateral margins of the cheeks, one just below the compound eyes and the other at about the level of the dorsal margin of the anteclypeus; anteclypeus with two large black spots laterad. Tegmina chiefly ochraceous buff, shading to paler apically; the claval vein, the claval suture, and the cubital vein margined more or less completely with fuscous. Legs chiefly ochraceous buff with some fuscous shadings; two rather large spots on the anterior femora, and the intermediate femora; one near the apex and the other near the base; posterior femora with a single spot near the apex; all the tarsi more or less clouded with fuscous; posterior tibiae with fuscous spots at the bases of the anterior lateral spines. Abdomen below chiefly blackish with the posterior margins narrowly ochraceous, with the genitalia ochraceous buff marked with blackish fuscous.

Length to apex of tegmina 7.2 mm.

Holotype, Mount Polis, Luzon, Philippine Islands.

LITERATURE CITED

Literature is cited in the text according to the designations given in the Bibliography (Metcalf 1944a, 1944b) listed below. The paper which has been published since the publication of the Bibliography is indicated below.

Evans, J. W. 1947a. A natural classification of leaf-hoppers (Jassoidea, Homoptera). Trans. Ent. Soc. London 98: 105–271.

Metcalf, Z. P. 1944a. Authors' List A-Z. A bibliography of the Homoptera (Auchenorhyncha) 1: 1–886.

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NEW SPECIES OF GALERUCINAE AND ALTICINAE WITH NOTES ON OTHER SPECIES

(COLEOPTERA: CHRYSOMELIDAE)

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New York State Museum, Albany, New York

The following notes and descriptions were prepared while the writer was attempting to classify undetermined leaf beetles in the collection of The Ohio State University. Four new species of Chrysomelidae are described and corrections in synonymy and generic disposition are made.

Euryscopa longicollis Jacoby

Euryscopa longicollis Jacoby is a valid species. Its pubescent scutellum will separate it from *E. lecontei* Crotch. *E. pusilla* Horn and *E. vittata* Lec. also have the scutellum pubescent but in these two species the pronotum is broader than long while in *E. longicollis* the pronotum is much longer than broad. *E. longicollis* has been found in Tucson and Hualpai Mts., Arizona.

Cryptocephalus mucoreus Lec.

Figure 4

Cryptocephalus mucoreus LeConte (1859, Smithson. Contrib. Knowl. vol. 11, p. 23) is a valid species. Jacoby, 1880, and later writers have listed it as a synonym of *C. basalis* Suff. (fig. 5). It differs from *basalis* in its more parallel form, finer pronotal and elytral punctation and different color pattern.

C. basalis is quite robust, widest across base of elytra which become narrower toward apex. Elytral punctures are large and deep, their diameter greater than half the width of the interspaces. The interspaces are convex. Apical third of elytra is black, except for round spots at apex, and the suture rather narrowly black. The sutural dark area does not reach scutellum as it does in *mucoreus*. Usually the humeral callus is distinctly darkened also. The color is quite constant in the series which the writer has seen from Texas and Arizona.

C. mucoreus is more cylindrical, the sides of elytra parallel. Elytral punctures are very small, their diameter about one-fourth the width of interspaces. The interspaces are flat. Elytra are black except for apical spots and a rather narrow L-shaped red area along basal and lateral margins. The humeral callus is not dark. *C. mucoreus* was described from Kansas and Texas and Blatchley records it from southern Indiana.

Metachroma angustulum Crotch

Metachroma parallelum Horn, 1892, is a synonym of *M. angustulum* Crotch, 1873. In this species the female (typical *angustulum*) is colored pale yellowish brown and the male (*parallelum*) black with pale legs.

Triarius santarosarum n. sp.

Figures 1, 2

Elongate, sides parallel. Elytra wider than prothorax at base. Upper surface yellow; elytra with sutural and discal stripes black, lateral and apical margins narrowly black; ventral surface black. Antennae with basal three segments yellow, outer segments dark brown or black.

Head smooth, shining, a little darker than pronotum. Inter-ocular distance two-thirds the width of head. Frontal tubercles prominent, not strongly swollen. Inter-antennal carina flat, short, not extending beyond antennal insertions. Second and third antennal segments short, third a little longer than second, together as long as fourth. Prothorax slightly wider than long, widest at apical third, lateral margins sinuate. Surface not strongly convex, except near lateral margins; shining; very minutely, closely punctulate. Median line slightly depressed, smooth.

Scutellum black, smooth, shining. Elytra elongate, sides and apex usually curled under. Surface alutaceous, very minutely punctulate; yellow with suture, narrow discal stripe and sides in apical half black. Epipleura reaching nearly to apical angle. A few very short hairs on surface near apex.

Body beneath black except head and prothorax; abdomen and sometimes mesosternum of female yellow, meso- and metathorax densely clothed with rather long white hairs. Prosternum does not extend entirely between front coxae. Last ventral segment of male deeply incised each side of middle, leaving a broad rectangular, median lobe; of female evenly rounded. Legs yellow, apex of posterior femora and outer side of tibiae black. Tibiae densely pubescent, femora moderately so. Each tibia with a strong spur on apex situated in emargination before the tarsus. Claws bifid.

Length 5.8 mm, width 2 mm.

Holotype ♂, allotype ♀, paratypes 7 ♂♂, 40 ♀♀, Santa Rosa Mts., California, May 27, 1946, D. J. and J. N. Knull collectors. Other paratypes: 1 ♀, Jacumba, California, May 18, 1941; 1 ♂, Hualpai Mts., Arizona, July 4, 1937; 1 ♂, Globe, Arizona, May 25, 1924. Holotype, allotype and paratypes are deposited in the Ohio State University collection. Paratypes also in the collections of the California Academy of Sciences, New York State Museum and the writer.

There is considerable variation in the size of the opening of the anterior coxal cavities. In some specimens the cavities appear to be completely closed, in others widely open. In some females the discal stripe is very narrow and occasionally broken. In many specimens punctation is lacking on elytra. The length varies from 4.5 mm to 7 mm.

T. santarosarum is very closely related to *T. trivittatus* Horn. It differs from that species in lacking the short median, basal elytral stripe; in possessing slightly more evident elytral and pronotal punctation, and in having apex of aedeagus narrower, more deflexed and more evenly rounded (figs. 2, 3).

Exora californica n. sp.

Figures 14, 15

Oblong, parallel. Dull reddish brown; head, legs, antennae, scutellum, meso- and metasternum black. Head smooth, shining, pubescent, a few punctures near the eyes. Occiput black to the tubercles; front entirely pale; tubercles well marked with transverse sinuate groove between the eyes. A rather strong depression at center. Antennae short, extending little beyond base of thorax; shining black or dark brown; segments short, broader than long, triangular. Pronotum one-half wider than long, little narrowed at apex, lateral margins regularly arcuate. Posterior angles obtuse, anterior angles thickened, rounded. Pronotum evenly convex, shining, minutely punctate, punctation a little more evident at sides. Elytra alutaceous, finely, closely punctate, punctures shallow, irregular; sparsely pubescent; humeri prominent; epipleura extending a little beyond the middle. Apex of elytra darkened.

Underside shining, pubescent, side pieces of metasternum strigosely sculptured. Prosternum convex, visible between the coxae. Front coxal cavities open. Legs black, bases of femora paler. All tibiae with spurs. Claws with basal lobe. Last ventral segment of male with a very short, truncate, depressed lobe at middle, aedeagus with long slender tip, sides of tip parallel.

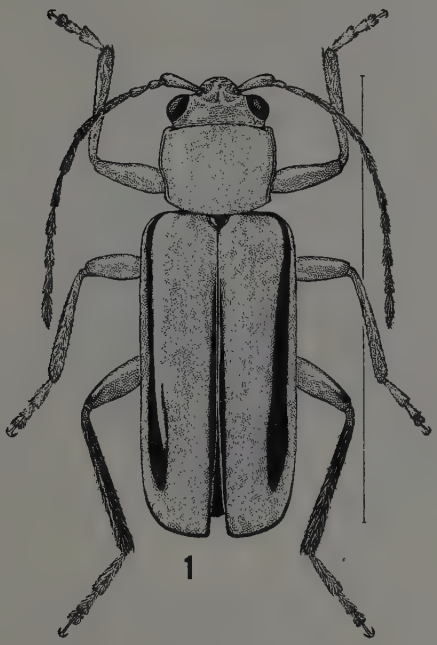
Length 5 mm, width 2.2 mm.

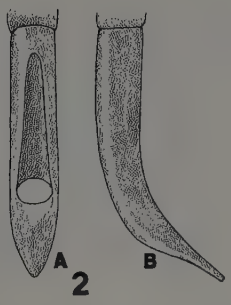
Holotype ♂, allotype ♀, paratypes 10 ♂♂ and 29 ♀♀, Santa Rosa Mts., California, May 27, 1946, collected by D. J. and J. N. Knull. Holotype, allotype and paratypes in the Ohio State University collection. Paratypes also in the New York Museum and the writer's collection.

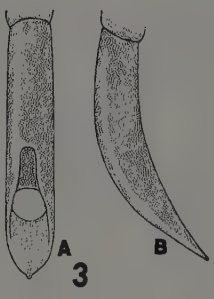
DESCRIPTION OF FIGURES IN PLATE I

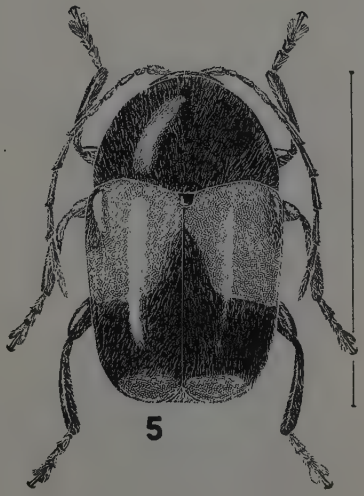
1. *Triarius santarosarum* n. sp., ♂.
2. Aedeagus of *Triarius santarosarum* n. sp.: A, dorsal view; B, lateral view.
3. Aedeagus of *Triarius trivittatus* Horn: A, dorsal view; B, lateral view.
4. *Cryptocephalus mucoreus* Lec., ♀.
5. *Cryptocephalus basalis* Suff., ♂.

Line equals 5 mm.









J.A.W.

This insect is very closely related to *Exora brevicornis* (Jacoby). External differences are very poorly defined. In general, in the California form, the punctation of the pronotum is more evident and the elytra have a more alutaceous surface, the pubescence is longer and more dense, and the elytral punctures not as well defined as in *E. brevicornis*. The only sure way to separate them is by the character of the aedeagus (figs. 13, 14). In the series at hand from California there is very little variation in color.

While the original description of *E. brevicornis* does not contain any characters which distinguish these two, the locality does give a good indication. *E. brevicornis* was described from Monclova, Mexico which is near Texas.

In addition to the type series, the writer has seen a series from the Hualpai Mountains, Arizona, which agrees with *E. californica* in the form of the aedeagus. This series is probably *californica* but differs from the type series in color. It is black except for pronotum and clypeal region and it has slightly stronger elytral punctation.

Luperaltica Crotch

The species of the genus *Luperaltica* have caused more than their share of confusion. Horn (1893) gave a fairly adequate definition of the two eastern species. The taxonomic history of the species is interesting. Say described *senilis* as an *Altica*. Leconte (1859) described *nigripalpis* in the genus *Longitarsus*. Six years later he described both of these species again (as *M. tincta* and *M. fuscula* respectively) in the genus *Malacosoma*. Crotch (1873) described the genus *Luperaltica* to contain *A. senilis* and *M. fuscula*. Horn (1889) suggested dropping the name *Luperaltica* because neither species fit the description. He placed *A. senilis* in *Systena*. Four years later Horn redescribed *Luperaltica* to avoid confusion and replaced both *senilis* and *fuscula*. He stated that *nigripalpis* is doubtless a synonym of the latter and lists *tincta* as a synonym of *senilis*. Fall (1907) described the third species as a *Luperodes*. Blatchley and Duckett reproduce Horn's descriptions nearly verbatim.

Luperaltica undoubtedly belongs in the Alticinae. The posterior femora of *L. senilis* are somewhat swollen, less noticeably so in other species. *L. nigripalpis* does have the habit of jumping. Both of these species are erroneously described as lacking spurs on the apex of hind tibiae, for each hind tibia does have a slender, slightly curved spur at the apex. The front coxae of *L. nigripalpis* may or may not be contiguous. This is a variable character which is of little value in identifying the species.

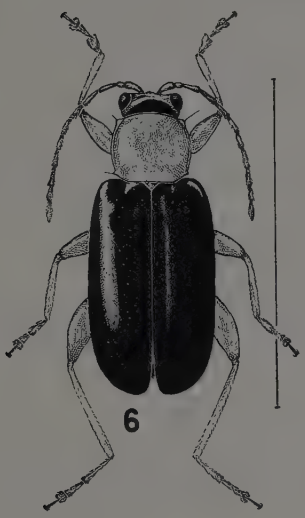
In nearly all males which I have seen, the tip of the aedeagus was visible without dissection. Because of this the aedeagus has been mentioned in previous descriptions as a short process at the middle of the apex of the last ventral segment. The transverse, antebasal groove of the pronotum is never very deep nor definitely limited. In some specimens, particularly of the new species here described, it is barely evident.

Luperaltica will, according to most keys to genera, be placed near *Palaeothona* Jacoby or *Aphthona* Foudras. It differs from these and *Longitarsus* Latr., which it resembles, in the greater length of the third antennal segment. In *Luperaltica* this segment is about twice as long as the second while in the other genera mentioned it is not or is only slightly longer than the second.

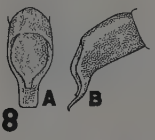
DESCRIPTION OF FIGURES IN PLATE II

6. *Luperaltica nitida* n. sp., ♂.
7. Aedeagus of *Luperaltica nitida* n. sp.; A, apical view; B, lateral view.
8. Aedeagus of *Luperaltica semiflava* (Fall): A, apical view; B, lateral view.
9. Aedeagus of *Luperaltica nigripalpis* (Lec.): A, apical view; B, lateral view.
10. Aedeagus of *Luperaltica senilis* (Say): A, apical view; B, lateral view.
11. Aedeagus of *Monomacra opaca* n. sp.: A, apical view; B, lateral view.
12. *Monomacra opaca* n. sp., ♂.
13. Aedeagus of *Exora brevicornis* Jacoby: A, dorsal view; B, lateral view.
14. Aedeagus of *Exora californica* n. sp.: A, dorsal view; B, lateral view.
15. *Exora californica* n. sp., ♂.

Line equals 4 mm.

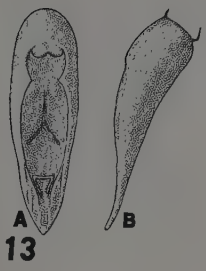

6

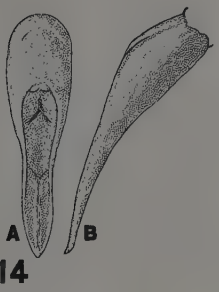
A
B
7

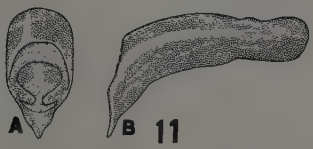

A
B
8

A
B
9

A
B
10


A
B
13


A
B
14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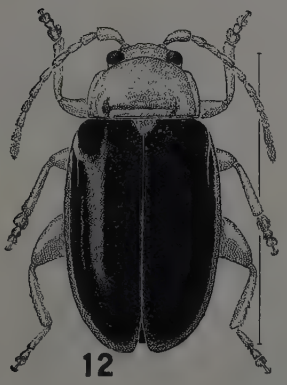
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J.A.W.

From *Systena* Clark, which has a similar, though more depressed form, it is easily distinguished by its open front coxal cavities. In some specimens the pronotum may have as distinct a transverse impression as certain species of *Altica* Geoff. From these *Luperaltica* may be distinguished by its narrower form, longer, more slender posterior femora, enlarged first segment of front tarsus of male and cylindrical aedeagus.

Altica senilis Say is hereby designated the type species of *Luperaltica* Crotch.

The following is a catalog of species in *Luperaltica* Crotch.

Luperaltica Crotch

Luperaltica Crotch, 1873, Proc. Acad. N. S. Phila. 25: 70. Horn, 1893, Trans. Amer. Ent. Soc. 20: 135. Blatchley, 1910, Coleop. Ind. p. 1203. Duckett, 1920, Md. Ag. Exp. Sta. Bull. 241: 140. Heikertinger, 1925, Koleop. Runds. 11: 57.

Genotype: *Altica senilis* Say (present designation)

Luperaltica senilis (Say) N. Y. Ga., Mo. *Eupatorium ageratoides*

Altica senilis Say, 1824, Jour. Acad. N. S. Phila. 4: 87.

Malacosoma tincta Leconte, 1865, Proc. Acad. N. S. Phila. 17: 206.

Systena senilis Say, Horn, 1889, Trans. Amer. Ent. Soc. 16: 271.

Luperaltica senilis Say, Crotch, 1873, Proc. Acad. N. S. Phila. 25: 70. Horn, 1893, Trans. Amer. Ent. Soc. 20: 136. Blatchley, 1910, Coleop. Ind. p. 1203. Blatchley, 1921, Jour. N. Y. Ent. Soc. 29: 25.

Luperaltica nigripalpis (Leconte) Pa., S. C., Iowa, Kans.

Longitarsus nigripalpis Leconte, 1859, Smithson. Cont. Knowl. 11: 26.

Malacosoma fuscula Leconte, 1865, Proc. Acad. N. S. Phila. 17: 206.

Luperaltica fuscula Leconte, Crotch, 1873, Proc. Acad. N. S. Phila. 25: 70. Horn, 1893, Trans. Amer. Ent. Soc. 20: 135. Duckett, 1920, Md. Ag. Exp. Sta. Bull. 241: 141.

Luperaltica fuscula var. *novellus* Crotch (Zimm.), 1873, Proc. Acad. N. S. Phila. 25: 70.

Luperaltica nitida n. sp. Texas

Luperaltica semiflava (Fall) Texas, N. Mex. *Gutierrezia microcephala.*

Luperodes semiflavus Fall, 1907, Trans. Amer. Ent. Soc. 33: 252.

KEY TO THE SPECIES OF LUPERALTICA CROTCH

1. Pronotum alutaceous; Eastern United States 2
   Pronotum shining; Texas 3
2. Elytra very indistinctly punctate, alutaceous; color varying from testaceous to black, elytra occasionally dull blue; aedeagus with broad apex (figure 9) ..... *nigripalpis* (Lec.)
   Elytra evidently, closely punctate, usually shining metallic blue-green; aedeagus with apex pointed, apex not deflexed (figure 10) ..... *senilis* (Say)
3. Aedeagus pointed at apex, apex deflexed (figure 7); elytra shining blue-green, very finely punctate ..... *nitida* n. sp.
   Aedeagus broad at apex (figure 8); elytra shining blue-green, punctation indistinct ..... *semiflava* (Fall)

Luperaltica nitida n. sp.

Figures 6, 7

Elongate oval, elytra much broader at base than prothorax. Color reddish yellow; occiput, vertex, metasternum and abdomen brown; elytra metallic blue-green. Surface strongly shining. Posterior femora long, reaching beyond end of abdomen.

Head shining brown above tubercles; tubercles and lower areas of face testaceous; labrum brown. Vertex with a few scattered punctures near eyes. Tubercles strongly delimited, transverse. Inter-ocular groove deep. Inter-antennal carina short, convex. Clypeus flat, it and labrum beset with long pale hairs. Antennae reaching middle of elytra, testaceous, slightly darker toward apex. Segments three, four and five equal, longer than 6–10, nearly as long as eleventh. Pronotum one-fourth wider than long, sides curved, widest at apical third. Anterior angle prominent, rounded, posterior angle acute, prominent. Surface evenly convex, shining, with

scattered very minute punctures. Antebasal, transverse groove very weakly evident. Scutellum triangular, brown, alutaceous. Elytra four times as long as wide, moderately convex, sides nearly parallel. Humeri prominent, a definite basal callus present, limited behind by a vague transverse depression at basal fourth. Surface shining, finely irregularly punctate. Epipleura testaceous, broad at base, suddenly narrowing at basal fourth, continuing to apical angle. Ventral surface testaceous, alutaceous, pubescent; metasternum and sides of abdomen darker brown. Prosternum extending narrowly but distinctly between front coxae. Front coxal cavities open behind. Mesosternum tuberculate between middle coxae. First abdominal segment swollen between hind coxae. Last ventral with a very narrow median groove, apex with short, broad lobe deflexed into body cavity. Posterior femora long, not greatly swollen. Posterior tibia with apical spur. First segment of front tarsus broad, wider than tibia at apex. First segment of middle tarsus broad, about as wide as tibia. First segment of hind tarsus slender, about one-third the length of tibia. Tarsal claws appendiculate, divergent. Aedeagus at apex narrowed to an irregularly rounded point, tip strongly deflexed, sides produced into thin lobes.

First abdominal segment of female not swollen between posterior coxae. Last abdominal segment straight across apex, median groove feebly indicated. First segments of front and middle tarsi normal.

Length 3.2 mm, width 1.5 mm.

Holotype ♂, allotype ♀, paratypes 3 ♂♂ and 6 ♀♀, Chisos Mts., Texas, July 17, 1946, D. J. and J. N. Knull collectors, also, 16 ♂♂ and 8 ♀♀, Chisos Mts., July 16 to 26, H. A. Wenzel collector. Holotype, allotype and paratypes in the Ohio State University collection. Paratypes also in collections of the writer and the New York State Museum.

There is some variation in color of head and epipleura in the paratypes. In some the head is entirely testaceous and the epipleura may be dark.

This species, because of its punctate elytra and separated coxae seems to be more closely related to *L. senilis*. However, it may easily be separated from that species and *L. nigripalpis* by its smooth, shining pronotum.

Luperaltica semiflava (Fall), new combination

Figure 8

Luperodes semiflavus Fall belongs in the genus *Luperaltica* rather than *Luperodes*. Externally this species is nearly identical with *L. nitida*. The pronotum is very slightly broader and less convex than in *nitida*. Elytral punctation is obsolete. The aedeagus, however, is quite different from that of *nitida*. It has a broad, truncate apex; apical margin deflexed; orificial plate broader than in *nitida:* and the sides moderately developed. *L. nitida* is so similar to *L. semiflava* that I had some hesitation in describing it as a distinct species. Perhaps it is only a subspecies or genetic variant of *semiflava*, but the great difference in aedeagi leads me to consider it distinct.

Besides the type in the Museum of Comparative Zoology, I have seen a specimen collected by John L. Ward in the Chisos Mts., Texas, August 1, 1949, on *Gutierrezia microcephala*.

Monomacra opaca n. sp.

Figures 11, 12

Oblong, depressed. Body entirely reddish brown; elytra dull metallic blue-green; lateral and apical margins fading to brown. Head finely alutaceous, a depression above each eye with coarse punctures. Eyes small, distance between them more than half the width of the head. A short median depression extends back from between tubercles. Frontal tubercles very indistinctly bounded. Frontal carina broad, not convex, alutaceous, a row of short hairs on each side. Tips of mandibles black. Antennae half the length of body, stout, thickly pubescent. Segments two, three and four gradually longer. Fourth nearly twice as long as second and longer than segments five to ten. Pronotum alutaceous, not punctate except for one or two deep punctures at sides. Slightly narrower in front, three-fifths as long as wide. Sides broadly margined, evenly arcuate. Anterior angles obtuse, posterior angles rectangular. Transverse

basal impression deep, limited at each side by a very deep, nearly circular depression. Scutellum brown, alutaceous. Elytra little wider at base than prothorax. Each elytron four times as long as wide. Lateral margins explanate, arcuate, more or less translucent, brownish. Surface alutaceous, finely, closely punctate. Female with one or two low, irregular, longitudinal carinae extending back from humerus. Male evenly convex. Epipleura broad, reaching apical angles. Ventral surface alutaceous, finely punctate, with moderately dense, evenly distributed pubescence. Last ventral segment of male with broad emargination at apex, of female evenly rounded. Prosternum widely separating front coxae. Front coxal cavities open. Posterior femora strongly swollen. Each tibia with sharp carina on outer margin. Apex of posterior tibia with a stout spur. First segment of front and middle tarsus of male greatly expanded, broadly oval, wider than tibia at apex. Tarsal claws appendiculate. Aedeagus short, cylindrical, apex acute.

Length 4.6 mm, width 1.8 mm.

Holotype ♂, allotype ♀, paratypes 9 ♂♂ and 13 ♀♀, Chiricahua Mts., Arizona, July 14, 1936, D. J. and J. N. Knull collectors. Holotype, allotype and paratypes in the Ohio State University collection, paratypes also in the writer's collection.

M. opaca differs from *Monomacra iris* (Oliv.) in being less shiny, more elongate and less convex. The elytra of *iris* are purple-blue and the legs, abdomen and outer segments of antennae are black.

Epitrix nitens (Horn), new combination

Crepidodera nitens Horn, 1888, should be placed in the genus *Epitrix* Foudras. Horn stated that "the form and facies suggest *Epitrix*" but since he did not observe elytral pubescence he found "it necessary to place it for the time in *Crepidodera*." I have seen several specimens from Ohio which do have scattered elytral hairs, thus requiring the transfer to *Epitrix*.

Hornaltica atriventris (Melsh.), new combination

Crepidodera atriventris Melsh., 1847, because it has open coxal cavities must be removed from the Crepidoderini. It is very similar in form to *Hornaltica bicolorata* (Horn) so I propose its transfer to the genus *Hornaltica* Barber. Judging from the description, I suspect that *Crepidodera solani* Blatchley also belongs in *Hornaltica*.

Laboratory Manual for First Year College Chemistry. *John W. Barker* and *Paul K. Glasoe*. McGraw-Hill Book Co. New York. 1951. xi+186 pp. $3.00.

Here is a first year college chemistry laboratory manual designed for a full year's use, assuming six hours of laboratory time each week.

The manual is divided into two main sections. The first consists of twenty well-chosen, carefully written, and clearly illustrated exercises. Each exercise, in addition to instructional matter, contains numerous questions and problems to further emphasize the principles followed. There is a nice balance between experimentation time and writing time required from the student. In addition, an *Addendum* at the conclusion of every chapter contains information to be studied or omitted as the individual instructor or student sees fit.

The use of ionic equations and the principles of oxidation-reduction are particularly emphasized whenever possible.

In the second part of the manual, the authors have devoted their efforts to qualitative analysis, following the usual scheme which involves the use of hydrogen sulfide.

In each group there are a series of preliminary tests with accompanying notes. The procedures for the groups appear in block outline form both for macro and semi-micro analyses. Special notes on each analysis follow these procedures. At the end of each group are a series of equations and questions.

The anion analyses, too, follow the usual pattern of dry tests, group separations and individual tests.

The appendix contains a detailed list of solutions for use in the qualitative scheme, a very helpful addition for people in charge of chemical supply rooms.

This manual should be quite worth while in any first year course of the type originally mentioned. It appears easily adaptable to almost any of the popular texts today.

ARTHUR H. BLACK

BIOLOGICAL NOTES ON FIVE HYMENOPTEROUS PARASITES OF PINE BUD AND STEM MOTHS IN OHIO

WILLIAM E. MILLER

Department of Entomology, Ohio Agricultural Experiment Station, Wooster

Incidental to biological investigations of three pine moths, the European pine shoot moth, *Rhyacionia buoliana* (Schiffermüller), the pitch twig moth, *Petrova comstockiana* (Fernald), and *Rhyacionia rigidana* (Fernald), which does not have a common name, some biological information on larval parasites was obtained. All parasites were in larval or later stages when they came under observation, and therefore detailed life history treatment here is limited to the advanced stages of the several species. The main points considered are length of the pupal stage, the period of emergence, and longevity of adults with and without food.

Numerous instances of parasitization by these hymenopterons are on record, but little has been published regarding their biology. The biological literature treats of only three of the parasites and consists for the most part of papers in which a modicum of information has been included incidentally.

MATERIALS, METHODS, AND PROCEDURE

Specimens which were reared under observation were recovered from field collections of host larvae in the course of sampling for seasonal history information, while adult parasites were obtained from emergence cages which contained host infested pine tips or twigs. Cork stoppered shell vials 25 by 95 mm were the containers used for holding both adults and immature individuals with their hosts. Usually these containers were occupied singly, but in some cases it was more convenient to keep several specimens in one vial. The vials and emergence cages were housed in a field type insectary at the Ohio Agricultural Experiment Station at Wooster.

Rearing began in June, 1951 and was complete by the end of July. The adult longevity studies ranged from the latter part of May to October, 1951, except in one case which will be noted further on in the text. The method used to provide food for adult parasites was that illustrated by Peterson (1949), consisting of a raisin mounted on a straight pin inserted into the cork used for stoppering a container. Raisins pinned in this manner and moistened periodically usually served for weeks, although occasionally it was necessary to replace some sooner because of contamination by micro-organisms. All living material was examined once daily at a regular hour, and therefore the durations given for stages and other periods are accurate to one calendar day. Most of the computed averages given are rounded to the nearest whole number.

Determinations were made through the courtesy of Mr. C. F. W. Muesebeck and his co-workers in the Division of Insect Identification, Bureau of Entomology and Plant Quarantine, Washington, D. C.

OBSERVATIONS

Before proceeding with the parasite discussions, the life cycles of the host species will be briefly reviewed. All three of the species undergo their complete development on pine and are intimately associated with the tree in all stages except the adult. *Rhyacionia buoliana* and *Petrova comstockiana* are univoltine, and both hibernate as partly grown larvae. The moths of the latter species issue during May and June, and those of the former during June and July. *Rhyacionia rigidana*

on the other hand produces two generations a year in Ohio and winters in the pupal stage. One moth flight (overwintering generation) occurs in April, and the other (summer generation) in July.

1. *Calliephialtes comstockii* (Cresson)[1] (Ichneumonidae). This species parasitized all three moths to a greater or lesser extent. Five larvae (four males and one female) were reared to the adult stage. They were feeding externally and singly on apparently full-grown host larvae when collected. Following the termination of feeding, whitish, semitransparent, silken cocoons were spun and were completed in less than a calendar day. Cushman (1927) mentions that *C. comstockii* is solitary on full-grown larvae of *Rhyacionia frustrana* (Comstock), but states that the cocoon is light brownish. The parasite larvae in the present observations began voiding their alimentary tracts soon after completing their cocoons. In some cases this process was noted to continue over several days. From the time the cocoons were spun until their occupants transformed to pupae there was an interval (prepupal period) which varied from 3 to 5 days. The time from pupation to eclosion from the cocoon varied between 7 and 11 days, and averaged 9 days. There was some evidence however, that the parasites did not leave the cocoons immediately upon shedding pupal skins but remained quiescent in them for a day or more before issuing. Emergence took place concurrently with that of the host moth in cages containing pine tips infested with *R. buoliana*. Adults also appeared during the respective emergence periods of the other two hosts, but from the summer generation only in the case of *R. rigidana*. The overwintering brood of this species very likely is attacked, but too few infested tips of that generation were observed for a conclusive record. The parasites issued from the first named host between June 14 and July 5 in 1950, and between June 6 and June 28, in 1951 with males emerging slightly ahead of females. Of 82 adults obtained 53 were males and 29 were females, the males outnumbering females almost two to one. Provided with food, 11 males lived from 9 to 52 days, averaging 30 days, and 8 females lived from 3 to 49 days, averaging 24 days. Eight unfed males lived an average of 5 days, varying between 3 and 6 days, and 6 unfed females likewise lived an average of 5 days, but varied between 3 and 7 days. The longevity of the adults provided with food was therefore more than five times as long as that of unfed adults. The last of the parasites obtained from *R. buoliana* in 1951 lived until August 9.

In early May of both years females of this species were seen in the field flying about the tips of young trees infested with *R. buoliana*. The difference of from four to six weeks between this occurrence and the appearance of adult parasites in the emergence cages probably constitutes the time required in nature for development from adult to adult.

2. *Eurytoma tylodermatis* (Ashmead)[2] (Eurytomidae). This parasite was obtained from *R. buoliana*, and also from *R. rigidana*. Seven larvae (three males and four females) were reared under observation to the adult stage. When collected the larvae were feeding externally and singly, six on apparently full-grown host larvae, and one on a pupa. List (1932) discovered a small percentage of the larvae feeding on host pupae of the cherry curculio, *Tachypterellus consors cerasi* List, and on newly emerged, but undersized, adult beetles. He apparently does not think the host was attacked in the pupal stage, however. He states that the injury caused by the parasite to larvae which are near maturity is not so great but that they may enter the pupal stage, or even live to become adults. Parker and Lamerson (1934) also take this view in presenting similar observations made upon the western apple curculio, *T. quadrigibbus magnus* List.

[1]One lot determined by Dr. B. D. Burks, and one by Miss Luella M. Walkley.

[2]One lot determined by Mr. A. B. Gahan, and one by Dr. B. D. Burks.

There was an undetermined interval of several days after termination of feeding by the parasite larvae before their alimentary tracts were voided. On the day following voiding of the alimentary tract the insects were pupae in all cases. No cocoons of any kind were constructed. The pupal period varied between 10 and 12 days for the 7 individuals, and averaged 11 days.

Parasite emergence from caged tips infested with *R. buoliana* began during the latter half of the moth emergence period. In 1950 it occurred between June 21 and July 21, and in 1951 between June 21 and July 16. Some parasites emerged in 1951 from the overwintering generation of *R. rigidana* between April 27 and May 17. Emergence from the summer generation took place within the same periods as from *R. buoliana*. Several individuals which had parasitized the generation of *R. rigidana* soon to enter hibernation issued late in the summer of 1951. Those which were not so far advanced at that time would no doubt pass the winter with the host and make up the spring flight.

Of 113 adult parasites obtained 85 were females and 28 were males, the females outnumbering males three to one. Regarding longevity of adults, 8 males with food lived from 3 to 35 days, averaging 11 days, and 33 females with food lived from 4 to 86 days, averaging 43 days. Pierce (1912) reported that adults of this species obtained from various weevil hosts lived an average of 26 days, with a maximum of 79 days. He gave a sex ratio not differing greatly from that above. The adults in the present observations were seen feeding only at night. Without food four males lived from 4 to 5 days, and 11 females lived from 3 to 12 days, averaging 5 days. Adults provided with food therefore lived about five times as long as unfed males, and fed females decidedly outlived fed males. The last parasites of the 1951 summer flight lived until September 29.

One of the individuals of this species which was reared under observation was taken as a secondary parasite of *R. buoliana*. When developing as such on this host it probably does so through *Calliephialtes comstockii*, a large insect which is relatively abundant, and which develops generally in advance of *E. tylodermatis*. A few other instances of secondary parasitization upon *R. buoliana* were encountered, but the hyperparasites were not reared through and identifications not made. The parasite under discussion however, seems most likely to be the one involved.

When kept in stoppered vials many of the adults of this and the other species were observed to gnaw away portions of the cork stoppers. This was doubtless the manifestation of a behavior which in nature serves to effect their escape from the host chamber.

3. *Hyssopus thymus* Girault[3] (Eulophidae). Representatives of this species parasitized *R. buoliana* and *P. comstockiana*. They fed externally on hosts in the larval stage and occurred gregariously. The size of the parasite colony seems to depend upon the size of the host larva, for in the burrows of 15 parasitized *R. buoliana* larvae of the fourth (hibernating) instar the number of pupae averaged 2.4, varying between 1 and 4, whereas in the later instars of both hosts, the number of adults emerging in 4 cases averaged 11.8, varying between 5 and 21. It should be mentioned that in two of the last mentioned colonies 14 and 24 pupae were counted, but only 12 and 21 adults emerged respectively from these, there being some mortality. The largest of the above colonies was obtained from a larva of *R. buoliana*. Friend et al. (1938) reported that the number of parasite pupae per bud in 1607 buds containing parasitized *R. buoliana* larvae averaged 3, and Friend and Hicock (1936) stated that they reared as many as 19 individuals from a single parasitized larva of this species. Cushman (1927) wrote that from 3 to 10 or 12 individuals develop on a single host of *Rhyacionia frustrana*.

Two larvae reared under observation to the adult stage transformed to pupae

[3]One lot determined by Mr. A. B. Gahan, and one by Dr. B. D. Burks.

on the day following the voiding of their alimentary tracts, and they underwent pupal periods of 12 days. These larvae spun no cocoons of any kind, and no cocoons were observed when pupae were found in the field. At least two generations occur on *R. buoliana* annually, one issuing in the spring and another in the summer during the moth emergence period. There is evidence that two generations occur similarly on *P. comstockiana*, one emerging in April and another in June concurrently with the emergence period of the moths. The winter is passed in the pupal stage in the burrow of the host. Friend et al. (1938) found evidence both in the field and in the laboratory that several generations occur on *R. buoliana*. These authors reported rearing the parasite from egg to adult in from 17 to 18 days at 24 degrees C. and 60 percent relative humidity.

Nineteen adults provided with food in the longevity studies lived from 4 to 90 days. The average length of life of the 19 was computed at 44 days. Seven unfed adults lived for periods of from 1 to 12 days, averaging 4 days. These seven were observed under artificial circumstances however, and not when they would have normally been in the adult stage. They were taken as pupae from mid-winter host collections, brought indoors, and kept at room temperature until emergence occurred and also throughout the longevity observations. The data show that the adults which were fed lived 11 times as long as those not fed. In 1951 the last parasite of the summer generation lived until September 1. Of 15 individuals selected at random for identification, 8 were females and 7 were males. Friend et al. (1938) kept adults of this species alive for five weeks with moist sugar and reported obtaining a preponderance of females.

4. *Agathis pini* Muesebeck[4] (Braconidae). This species parasitized *P. comstockiana*. Larvae were observed feeding singly and externally on apparently full-grown caterpillars. Prior to pupation they spun white silken cocoons. In the insectary in 1951 the parasites issued from June 1 through June 27. In general, emergence lagged somewhat behind that of the host. Males emerged somewhat ahead of females, and of 36 adults obtained 20 were males and 16 were females. Seven unfed male adults lived from 3 to 6 days, averaging 4 days, and 7 unfed female adults lived from 3 to 7 days, averaging 5 days. Eight male adults provided with food lived from 1 to 14 days, averaging 7 days, and 5 female adults provided with food lived from 5 to 10 days, averaging 8 days. The adults receiving food thus lived slightly more than one and a half times as long as unfed adults. The last adult lived until June 29 in 1951.

5. *Perilampus fulvicornis* Ashmead[5] (Perilampidae). This species was found to be a secondary parasite of *P. comstockiana* through *Agathis pini*. Four of the larvae, which were solitary, external feeders, were reared to the adult stage. A period (prepupal period) varying between 1 and 3 days elapsed from the time the gut was voided until pupation took place. The duration of the pupal stage averaged 11 days, varying from 8 to 13 days. In these, as well as in a number of additional cases observed, the immediate host remained alive until after completing its cocoon. The hyperparasites did not themselves construct cocoons but underwent the latter part of their development within the host cocoons.

In 1951 the adult parasites issued over a period of 16 days in the insectary, beginning on June 23. On this date moth emergence was already complete, and emergence of the primary host was nearly so. Provided with food, 4 parasites remained alive in the vials from 5 to 19 days, averaging 12 days, while 7 without food lived from 2 to 8 days, averaging 5 days. The individuals which were fed therefore lived a little more than twice as long as those which were not fed. The

[4]Determined by Mr. C. F. W. Muesebeck.

[5]Determined by Dr. B. D. Burks.

last one lived until July 19. Of 14 adults obtained 6 were females and 8 were males.

Some indication of the length of the life cycle of this species lies in the fact that three lots of host infested twigs had been confined in the insectary for over six weeks, and a fourth lot for over four weeks prior to emergence of the adults.

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The Origins of Modern Science, 1300–1800. *H. Butterfield.* The Macmillan Company. New York. 1951. x+187 pp. $3.00.

The author has previously published books dealing with political affairs during the Napoleonic era, with George III during the American Revolution, and with Machiavelli. He organized the teaching of the history of science at Cambridge University, and there delivered the first series of lectures on the subject. This series is reproduced in the present volume.

He begins with the early significant scientific work done in Paris in the fourteenth century and its challenge to Aristotelian authoritarianism. He comes down to Buffon, Bonnet, Cuvier, and Lamarck, who laid the basis for Darwinism and the revolution in scientific thought in the nineteenth century.

We find that Copernicus had a lot of old and inadequate ideas in his system; Galileo was not much of an experimenter and did not drop the weights off the leaning tower of Pisa; Harvey got his inspiration and much of his training at the great University of Padua, which was inspired by the early Moslem thinker, Averroes; and the ground-work of Newton's synthesis was laid by many earlier scientists Butterfield shows how hard it was for science to feel its way toward modern conceptions.

The author should have been clearer on the general significance of it all. He does not have enough summarizing sentences and paragraphs. However, he is thorough, careful and reliable.

Butterfield feels that the scientific revolution of the seventeenth century has had a more profound influence upon civilization than the Renaissance or the Reformation or anything that has happened since the rise of Christianity. This revolution, he states, has been producing a brave new civilization that can "cut itself away from the Graeco-Roman heritage in general, away from Christianity itself . . . "

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